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CONTENTS

The Arctic Char of the West Coast of Hudson Bay

By Wm. M. Sprules

Central Fisheries Research Station[1]
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ABSTRACT

A preliminary survey of the Arctic char (*Salvelinus alpinus*) in the vicinity of Term Point, N.W.T. on the west coast of Hudson Bay, was carried out from August 12 to September 13, 1948, to augment the biological data pertaining to this species and assess its importance in the area studied. Information relative to the rate of growth, food and spawning habits of sea-run and landlocked populations was obtained. The dependence of the Eskimo residents on this species as a food coupled with the limited supply would seem to preclude the establishment of a commercial char fishery in this area.

INTRODUCTION

The arctic char, *Salvelinus alpinus*, is circumpolar in distribution and anadromous in cold coastal streams throughout its range. In Canada it is reported from streams entering the Gulf of St. Lawrence, the coast of Labrador, the northern coast of Canada and islands to the north and Hudson Bay (Dymond, 1947). The Arctic char is anadromous in streams entering the west coast of Hudson Bay as far south as the Churchill River. Occasional specimens have been reported from as far south as the mouth of the Nelson River, but these are unauthenticated. It abounds in the estuaries and rivers of the northern part of Hudson Bay and decreases in abundance in the rivers at the southern limit of its distribution. The speckled trout, *Salvelinus fontinalis*, occupies a similar ecological niche in streams entering Hudson Bay south of about 58° N. Lat. (Doan, 1948). It is probable that the distribution of these species overlaps in the coastal streams between the Churchill and Nelson Rivers.

The Arctic char has become landlocked in many regions throughout its range and through isolation several distinct forms have arisen which have been described as separate species. Dymond (1947) considers that certain of these may be found to be synonymous with *alpinus,* while others, such as the red trout of Quebec, *Salvelinus marstoni,* and the Dolly Varden of western America, *Salvelinus malma,* should be regarded as subspecies of *alpinus.* Landlocked populations occur in many freshwater lakes along the west coast of Hudson Bay.

Large quantities of Arctic char are used by the Eskimos of the Hudson Bay district where it forms an important source of meat, both for native consumption and for dog feed. This species is called "ekaluk" by the Eskimos and is referred to as "sea trout" or "Hudson Bay salmon" by the local white residents. Gill nets are fished in the coastal shallows and fresh water lakes by those fortunate enough

[1]Present address: Department of Fisheries, Ottawa.

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to possess such gear. Others rely upon more primitive, but quite efficient, methods of capture, which include still fishing with lures fashioned from sharpened nails and bits of walrus ivory, spearing and trapping. The last method consists of building a rock enclosure, generally at the mouth of a stream, which is flooded at high tide and retains the fish in a shallow pool from which they can be removed readily when the tide recedes. The spears, which consist of a centre tyne of sharpened metal and two flexible outside tynes of bone, each bearing a recurved metal hook, are used mostly for fishing in the winter through holes cut in the ice in freshwater lakes. Most of the fish caught are used immediately, but on occasion quantities are pickled in wooden barrels, dried or smoked, for use at a later date.

In recent years interest in the development of a commercial fishery for Arctic char along the west coast of Hudson Bay has been stimulated by the development and expansion of the port at Churchill, Manitoba, and the ready market for fish products which has existed. In 1945 a sample of char was canned experimentally by Mr. F. Martin, a trader in the Churchill district, and the product received a favourable report from the Pacific Experimental Station of the Fisheries Research Board of Canada, where it was tested. It is probable that a canned product of high quality could be developed if handled professionally. Permission to fish for Arctic char on a small commercial scale was granted to Mr. J. Ingebrigtsen of Churchill in 1932 by the Minister of Fisheries. Experimental nets were to be set and a record of the catch submitted to the Department of Fisheries, where the data could be analysed and used as a criterion of the advisability of establishing a fishery. Unfortunately, the sailing vessel used by Mr. Ingebrigtsen was not equipped with auxillary motors and he was unable to reach the best fishing areas owing to adverse weather conditions. Nets of 5¼-inch mesh set in the mouth of the Churchill River during early June produced an average of about 25 pounds of char per 100 yards of net per night (11.4 kg. per 100 m.), while at Sentry Island, situated off the west shore of Hudson Bay 150 miles north of Churchill, the same nets produced an average of 150 pounds of char per 100 yards per night during the latter part of July. He felt that much better catches could be obtained farther north, where a similar operation would prove profitable, but was unable to finance the larger equipment required for such a fishery. Approximately 2,000 pounds of lightly salted "sea trout" were sold locally on his return to Churchill. As far as is known by the author, no other attempts have been made to establish a commercial fishery for Arctic char on the west coast of Hudson Bay.

Little scientific work has been done relating to the Arctic char in Canada and much of the biology of this species is still relatively unknown. Since the Eskimos rely to such an extent on the char for food, an investigation of the life history and migrations of this species, and also a proper assessment of the populations in the Hudson Bay district, should be made to provide data which could be used as a basis for the establishment and regulation of any proposed commercial fishery.

A preliminary investigation of the Arctic char was carried out between August 12 and September 13, 1948, by the author, in company with Mr. P. Zamick.

Data were obtained from Whiterock Lake, the Wilson River, Wilson Bay, Pistol Bay, Littlefish Lake and the coast of Hudson Bay in the vicinity of Term Point, Northwest Territories, located on the west shore of Hudson Bay at 62° 10′ North Latitude, approximately 250 miles north of Churchill, Manitoba.

DESCRIPTION OF THE AREA

Term Point is located at the tip of a small island which is cut off from a long peninsula by means of a narrow strip of sea known as Hell's Gate. The Peninsula projects approximately 25 miles into Hudson Bay in a southeasterly direction and is bounded on the southwest by Wilson Bay and on the northeast

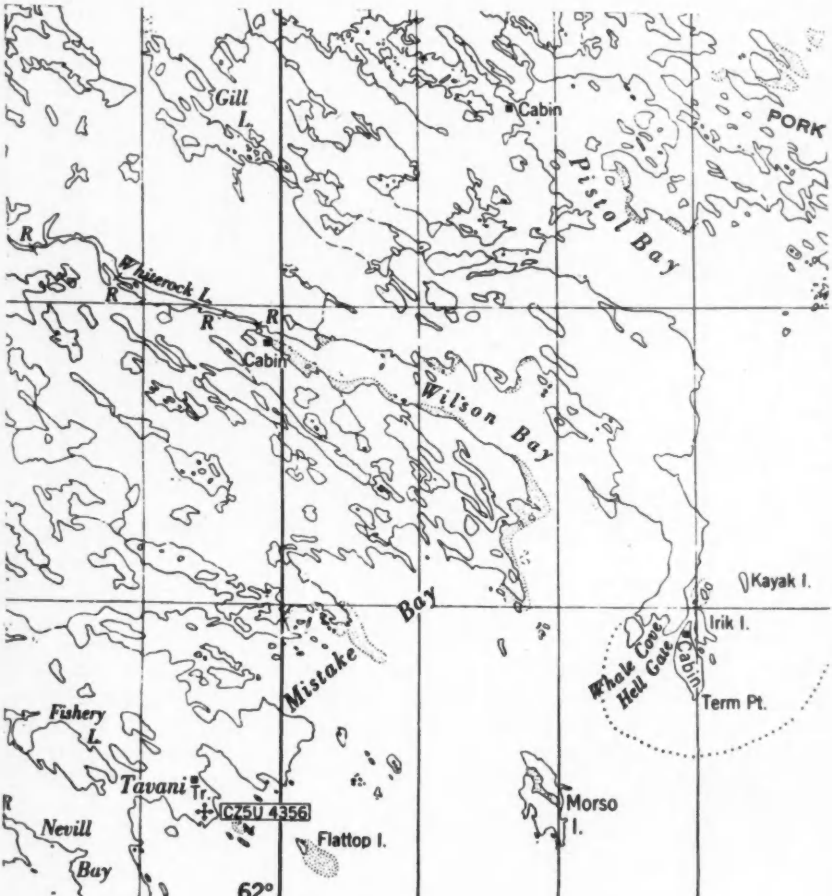

Figure 1. Map of the region in which Arctic char were studied. The area shown extends from 62° 0′ to 62° 30′ N.L., and from 92° 20′ to 93° 20′ W.L.

by Pistol Bay. Littlefish Lake is situated on the peninsula at the north end of Hell's Gate.

The Wilson River originates approximately 60 miles inland from the head of tide in an unmapped area, south of Chesterfield Inlet and flows southeasterly to empty into Wilson Bay. There are numerous small lakes along the course of the river which are little more than expansions of the main river. The largest of these are Derby Lake, Maze Lake and Whiterock Lake. The river drops about 250 feet throughout its length, with the steepest gradient occurring in the coastal region between Whiterock Lake and the mouth of the river.

FIGURE 2. Looking northwest across Hell's Gate (right background). Note the two belugas in the left foreground.

Geologically the Term Point district lies within the boundaries of the Pre-cambrian Shield and consists of an exposed granite mass of sedimentary, metamorphic and volcanic origin which has been smoothed and rounded by glaciation. Scattered flats of gravel are found among the granite mounds and numerous freshwater pools and lakes occur in the depressions in the rock mass. The coastline is rugged and rises abruptly from the sea so that there is a minimum of tidal flats exposed during low tide.

The area lies approximately 200 miles north of the tree line and the most luxurious vegetation consists of stunted willows with stems one-half inch in diameter which creep along the rock. The gravel flats support a sparse growth of grass and herbs which reach a height of from six to eight inches in protected areas and various lichens grow on the rock surface.

EQUIPMENT AND METHODS

The field party was flown from Churchill to Term Point where a base camp was established. From this base, trips were made along the coast and into the Wilson River system with a canoe and outboard motor.

A total of 216 fish was examined, including 64 Arctic char captured in salt water, 34 sea-run char from the Wilson River system, 46 landlocked char netted in Littlefish Lake and 49 lake trout, *Cristivomer namaycush,* 11 tullibee, *Leucichthys artedi,* nine round whitefish, *Prosopium cylindraceum quadrilaterale* and three Arctic grayling, *Thymallus signifer,* all taken in the Wilson River system. Two Arctic grayling, one lake trout and two Arctic char were caught by angling in Whiterock Lake and the rest of the specimens were captured in gill nets, which ranged from 1½- to 5½-inch mesh.

The length to the fork of the tail, weight and sex of each specimen were recorded in the field. Scale samples were preserved and age determinations were made from these at a later date. A qualitative analysis of the food utilized was made by examination of the stomach contents of 162 fish. Nine Arctic char, which were in good condition when removed from nets set in salt water at Hell's Gate were tagged and released between August 18 and August 28. Tags number 80, 100 and 101 were used on August 18, number 102 on August 27 and numbers 103, 104, 105, 106 and 108 on August 28. These were of the celluloid disc type attached by means of a pin inserted through the flesh of the dorsum.

RESULTS

Sea-run Arctic Char

The average length of the 98 sea-run char taken in the sea and in freshwater was 20.8 inches (528 mm.). The smallest specimen measured 12.5 inches 317 mm.) and the largest 32.5 inches (825 mm.). Fifty per cent of the catch fell within the length range from 18.0 to 21.0 inches (457–533 mm.). The average weight of these specimens was 4.3 pounds (1.95 kg.) with 56 per cent of the catch falling into the weight range between 2.0 and 4.0 pounds (0.9–1.8 kg.). The least weight recorded was 0.75 pound (0.34 kg.) and the greatest was 16.0 pounds (7.3 kg.).

The maximum size attained by Arctic char in this region is reported as 36 inches (91 cm.) in length and 20 pounds (9.1 kg.) in weight (Hinks, 1943). Mr. Ingebrigtsen included a photograph of a char in the report of his 1932 test fishery north of Churchill, which was labelled 38 inches and 26 pounds (96 cm. and 11.8 kg.). It is probable that even larger specimens have been caught on rare occasions, but no authentic record has been filed. The largest specimen obtained in a collection of fish from Netilling Lake on Baffin Island in 1925 was 28 inches long and weighed nine pounds (71 cm. and 4.1 kg.; Halkett and Soper, 1928).

The char obtained in the present survey were from 4 to 22 years old (Table I). The most common age group was 9 years and 70 per cent of the fish were from 8 to 11 years old inclusive. The age recorded represents the number

TABLE I. The age frequency distribution of 96* sea-run Arctic char taken in the Wilson River system and Hudson Bay at Term Point, between August 13 and September 10, 1948, showing the number of males and females and average length and weight for each age group.

Number of annuli	Number of specimens			Fork length in inches		Weight in pounds	
	Total	Male	Female	Range	Average	Range	Average
4	1	1	—	12.50	12.50	0.75	0.75
5	3	1	2	14.25–15.75	15.00	1.25–1.75	1.50
6	3	2	1	15.25–16.75	16.08	2.00	2.00
7	7	1	6	16.75–18.50	17.50	2.00–2.50	2.29
8	14	4	10	17.50–19.00	18.41	2.50–2.75	2.68
9	20	8	12	18.50–20.25	19.43	3.00–3.75	3.38
10	17	5	12	19.00–23.75	20.57	3.50–4.25	3.75
11	16	5	11	20.50–23.75	22.25	4.00–5.50	4.89
12	4	1	3	23.00–24.50	23.69	6.00–6.75	6.25
13	3	2	1	23.25–26.00	25.08	6.00–7.00	6.67
14	2	—	2	24.25–25.75	25.00	7.25–7.50	7.38
15	—	—	—	—	—	—	—
16	1	—	1	26.75	26.75	8.25	8.25
17	3	3	—	30.00–32.50	31.00	10.50–12.75	11.58
18	1	1	—	29.50	29.50	12.00	12.00
19	—	—	—	—	—	—	—
20	—	—	—	—	—	—	—
21	—	—	—	—	—	—	—
22	1	1	—	32.25	32.25	16.00	16.00

* Two additional specimens were obtained but scale samples were not retained and thus the age could not be determined. These included a male 28.50 inches long, weighing 8.75 pounds and a female of 25.25 inches and 6.5 pounds.

of completed annuli found on the scales, but since the fish were caught during late August and early September, an additional summer's growth had been added since formation of the last annulus. Thus, the average length and weight of specimens shown for each age group in Table I are close to maximal values. No significant differences were found between the rates of growth of males and females, or fish captured in the sea and those obtained in fresh water.

Sixty-two of the 98 fish examined were females and 36 were males. Although females made up 63 per cent of the catch, males predominated in the older age groups and constituted 64 per cent of the 13- to 22-year-old fish.

A total of 14 mature char was obtained which included seven males and seven females. Only six per cent of the sea-run char taken in salt water were mature, while 29 per cent of the freshwater specimens were mature. The youngest mature fish was a female nine years old which was 19 inches long and weighed three pounds. Mature and immature fish were found in each age group from 9 to 14 inclusive and all the individuals older than 16 years were mature. No 15-year-old fish were obtained and the single specimen belonging to the 16-year age group appeared to be immature. Only the specimens which showed large well-developed gonads and would spawn during the fall of 1948 were considered to be mature. It is probable that the char do not spawn every year after maturity is reached and

thus certain specimens represented as immature in this report actually may be mature. A spawning cycle of two years or more is not uncommon in fish populations of northern latitudes.

An indication that spawning occurs in fresh water during the fall was obtained as three individuals, one male and two females, which were partially spent, were netted in Whiterock Lake during the first week of September. In addition, mature char taken in fresh water were characterized by the secondary sexual characteristics commonly associated with salmonids in spawning season. The change in the females was slight, although the silver sheen found in salt water specimens disappeared and the general colour pattern was intensified. However,

FIGURE 3. The mouth of the Wilson River just above high tide level.

a marked change occurred in the males. The lower jaw protruded considerably and terminated in a bulb of spongy tissue which was recurved against the tip of the upper jaw. The body was covered with a layer of spongy tissue and the scales were partially reabsorbed. The belly assumed a brilliant orange-red hue which spread over the sides and faded dorsally. The ventral fins were suffused with colour and the black and white borders stood out prominently.

The stomachs of all the char taken in Whiterock Lake were empty, which indicates that char do not feed for some time at least after entering fresh water. Two specimens were obtained from the mouth of the Wilson River, 100 yards above the head of tide. One of these was empty and the other contained a small sculpin, which had been taken in salt water. Only two of the 30 stomachs examined of char from salt water were empty. Sand-lance, *Ammodytes americanus*, was the most important single food item and occurred in 23 of the 28 stomachs

which contained food. An unidentified sculpin occurred in nine stomachs, one stomach contained a ninespine stickleback, *Pungitius pungitius*; fish remains were found in two stomachs and amphipods in two stomachs.

Landlocked Arctic Char

A sample of landlocked Arctic char was obtained in Littlefish Lake, a small freshwater lake located on the west shore of Hell's Gate about 15 feet above the high tide level. Run-off water from the surrounding granite slopes drained into the lake and the only outlet consisted of overflow which entered Hell's Gate during periods of high water. There was no distinct outlet channel and the overflow entered the sea as a broad, shallow sheet of water. Although char could not reach the lake from the sea at the present time, it is probable that during periods of abnormally high tides associated with maximum overflow from the lake, an entry could be made.

One 1½-inch mesh gill net and one 2½-inch mesh net, each 50 yards (49 m.) long, were set in Littlefish Lake for 24 hours on August 14. A total of 95 char were obtained, of which 46 were examined and 15 preserved in formalin for future study.

The average length of the 46 landlocked char which were examined in the field was 11.5 inches (292 mm.). The smallest specimen measured 6.25 inches (159 mm.) and the largest 15.25 inches (387 mm.). The average weight was 9.1 ounces (261 g.) and the weight range of the sample was from 1 to 22 ounces (28–624 g.). These fish were from 2 to 15 years old (Table II). The most common age group was 10 years and 50 per cent of the specimens were from 9 to 12

Table II. The age frequency distribution of 46 land-locked char netted in Littlefish Lake, Term Point, Northwest Territories, on August 14, 1948, showing the number of males and females and the average length and weight for each age group.

Number of annuli	Number of specimens			Fork length in inches		Weight in ounces[a]	
	Total	Male	Female	Range	Average	Range	Average
2	3	2	1	6.25–6.75	6.42	1.0	1.00
3	1	—	1	6.50	6.50	1.5	1.50
4	2	—	2	7.25–7.50	7.38	2.0	2.00
5	1	—	1	7.50	7.50	2.0	2.00
6	3	1	2	8.00–9.75	9.08	3.0–5.0	4.33
7	2	—	2	9.75–10.75	10.25	4.0–5.0	4.50
8	2	1	1	10.75	10.75	7.0	7.00
9	5	3	2	10.50–11.75	11.20	8.0	8.00
10	7	4	3	11.50–13.00	12.29	7.0–10.0	9.00
11	5	3	2	11.75–12.75	12.10	9.0–12.0	10.00
12	6	2	4	12.50–15.25	13.79	9.0–20.0	12.67
13	4	2	2	13.50–13.75	13.56	14.0–15.0	14.25
14	3	1	2	13.50–14.00	13.83	15.0–16.0	15.67
15	2	1	1	14.75–15.00	14.87	18.0–22.0	20.00

[a] One ounce = 28.35 grams.

years old inclusive. The average length and weight of fish in each age group approximates a maximum since the age represents the number of completed annuli found on the scales and an additional summer's growth had been added at the time of capture.

The rate of growth of the landlocked char was much slower than that of the sea-run char. For example, the average length and weight of ten-year-old landlocked specimens was 12.3 inches (312 mm.) and 9.0 ounces (255 g.) compared with an average length of 20.6 inches (523 mm.) and an average weight of 3.75 pounds (1700 g.) in sea-run char of the same age.

Twenty-six, or 57 per cent of the 46 landlocked char examined were females.

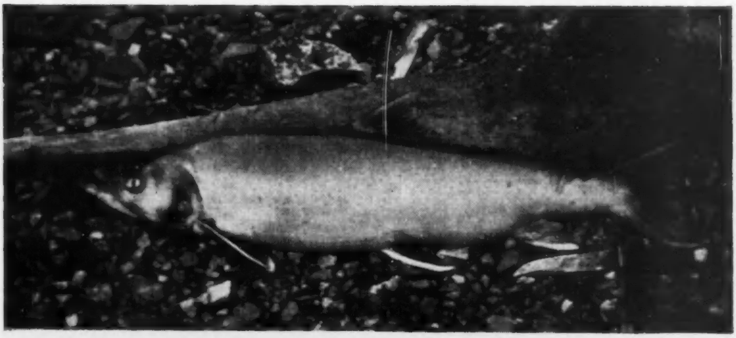

FIGURE 4. *Above:* Male sea-run Arctic char from Whiterock lake—30 inches and 10½ pounds. *Below:* A simple hand line with ivory lure, and a three-tyned spear, used by Eskimos to capture Arctic char.

The younger age groups were composed predominantly of females and 75 per cent of the specimens from two to seven years old inclusive, were females.

It was found that the landlocked char matured at a much earlier age than the sea-run specimens. Mature individuals were found in each age group obtained, and two of the three two-year-olds captured were mature and appeared ready to spawn. Forty-six per cent of the specimens were mature. The female specimens which were considered mature contained well developed gonads with large eggs, while mature males possessed an enlarged white gonad. Both males and females were obtained in the older age groups which contained undeveloped gonads and were classed as immature specimens. However, it is probable that many of these were mature but were not going to spawn that fall. Thus a spawning cycle of more than one year's duration, like that found for the sea-run specimens, was indicated. No spent or partially spent individuals were obtained, but it was obvious from the appearance of the mature specimens that spawning would occur during the late fall. This was substantiated by residents of the area who have observed the adults on the nests through the first ice each fall. The stomachs of all the landlocked char obtained were examined and 35 or 76 per cent were empty. Of the 11 stomachs that contained food, sticklebacks, *Gasterosteus aculeatus*, were found in three stomachs, unidentified fish remains in three and small bivalve shells belonging to the family Sphæridæ in five stomachs.

Other Species

Several species other than char were netted in Whiterock Lake and the Wilson River between August 31 and September 10 and included grayling, tullibee, round whitefish and lake trout.

Three grayling were obtained which measured 12¼, 14¼ and 14½ inches in length and weighed 15, 16 and 24 ounces (311, 362 and 368 mm.; 425, 453, and 680 g.). These specimens were 8, 9 and 10 years old respectively and all appeared to be mature. Insect remains were found in all three stomachs and remains of an unidentifiable fish were found in one of the stomachs. The smallest specimen was captured in a 1½-inch mesh gill net set in shallow water along the lake shore and the remaining two were taken by angling at the foot of a rapid in the river.

A total of 11 tullibee was examined. The smallest specimen was an immature female two years old, which measured 7¼ inches in length and weighed four ounces (184 mm. and 113 g.). The largest specimen obtained was a mature female 12 years old which measured 16 inches in length and weighed 32 ounces (406 mm. and 907 g.).

Seven of the nine round whitefish obtained were ten years old and averaged 13.9 inches in length and 14.7 ounces in weight (353 mm. and 417 g.). One eight-year-old was caught which was 12¾ inches long and weighed 11 ounces (324 mm. and 312 g.) and one 11-year-old which was 17 inches long and weighed 32 ounces (431 mm. and 907 g.). All the specimens appeared to be mature and ready to spawn.

Data pertaining to the rate of growth, maturity and food of 49 lake trout were obtained. The specimens ranged in length from 12 to 33¼ inches (305–843

mm.) and from three-quarters to 15 pounds (0.34–6.8 kg.) in weight. The average length of the catch was 21½ inches and the average weight was 4¼ pounds (546 mm. and 1.87 kg.). The larger fish were characterized by large heads which were disproportionate to the long, thin bodies. This condition is of common occurrence in lakes of northern latitudes where the growing season is of short duration and a meagre food supply exists.

The youngest lake trout were eight years old and averaged 12.1 inches in length and three-quarters of a pound in weight (307 mm. and 0.34 kg.). The oldest specimen appeared to be 41 years old and was 32 inches long and weighed 15 pounds (812 mm. and 6.8 kg.). The marginal annuli were crowded on the scales of the older fish and thus it was difficult to determine the age of these specimens with the same degree of confidence arrived at for the younger specimens. Twelve-year-old fish were most abundant in the catch and these averaged 18.9 inches in length and 2.4 pounds in weight (480 mm. and 10.9 kg.). Sixty-nine per cent of the catch was between 8 and 15 years old inclusive.

The nature of the gonads indicated that individuals of this species do not spawn every year in this locality. Spawning occurs during the early fall, since five individuals were taken in a spent or partially spent state.

The stomachs of 47 per cent of the lake trout examined were empty. Of the remaining 26 stomachs, 23 contained fish remains, two contained gravel and one contained vegetable debris.

DISCUSSION

Spawning

It was necessary to terminate the survey in early September before the char were spawning in quantities and thus few facts pertaining to the spawning habits were obtained. The presence of char, in Whiterock Lake, characterized by silver sea coloration was evidence that this species runs into fresh water during the early fall. Nine char were tagged at Hell's Gate from August 18 to 28, but no returns were obtained from nets set in Wilson River Bay and the Wilson River at later dates in 1948. Eskimo fishermen captured two of these fish during the summer of 1949. Both had been tagged on August 28, 1948, at Hell's Gate; one was caught on July 28 at Tavani, about 25 miles W.S.W. of Hell's Gate, and the other at Hell's Gate on August 31, 1949. These recoveries add support to the thought that either the char do not migrate far from the spawning streams, or they return to the same streams each year at spawning time. Further, the initial return of the tags shows that an extensive tagging programme should provide considerable data relative to the movement of Arctic char in Hudson Bay.

The local inhabitants were questioned and were of one accord in their accounts of the spawning habits of char. They stated that quantities of char were netted along the coast during the early summer but that the catch decreased during August and only an occasional specimen was obtained at later dates. The fish begin to move into the estuaries of the large rivers in late July and early August and are congregated at the head of tide by late August. Evidently some time is spent in this brackish water before the fish ascend the rapids into the fresh-

water system. The ascent is made, in general, during a spring tide or during periods of heavy rainfall which swells the rivers.

Spawning takes place late in September and through October, just before and during the time the first ice makes in the fresh-water lakes along the river systems. The eggs are deposited on gravel beds in from six to fifteen feet of water in Whiterock Lake and in shallower pools below rapids in the river. The Eskimos crawl out on the ice and locate the nests which are readily discernible. The male char can be seen by the nests and the Eskimos capture these by means of long-handled spears which are thrust through a hole chopped in the ice above a nest. Generally only from one to three males can be obtained from one hole, but as many as seven have been taken. Evidently only males are taken in this way, indicating that the females either retire to other areas in the lake or return to the sea immediately after spawning. The eggs are still visible at break-up the following spring and probably hatch shortly after open water appears.

The adult char leave the lakes as soon as the shore ice disappears. Even before the ice breaks up on the open lakes the char may be seen crowding along the flood waters near the shore in the rivers. The Eskimos did not know how long the young char remained in fresh water, but it is probable that at least one year is spent there prior to their first migration to the sea.

This concept of the spawning habits of Arctic char is in agreement with data obtained by other investigators. Halkett and Soper (1928) state that char were speared in Netilling Lake at the edge of the ice between May 10 and June 1, 1925. Further, none was obtained in the lake during the summer and large numbers were taken along the coast during August. Small char were observed among the rocks in the lake in July and August. Manning (1942) obtained heavy catches of char at sea during July and found that they were most abundant in coastal areas in the vicinity of streams on Southampton Island. None was obtained off Walrus Island, which is approximately thirty miles out to sea. He states that the char enter the stream mouths in August and ascend the streams when there is sufficient water. Grainger (1948, unpublished) accompanied the Shaw Steamship Company Expedition to Frobisher Bay as Government Observer and noted that the char catch during July and August was directly proportional to the distance from the river mouth fished, with best results obtained close to the river.

In the present survey the catch of char in the sea at Hell's Gate gradually fell off during August and only an occasional individual was netted in early September. Specimens were obtained in Whiterock Lake and the Wilson River early in September and several of these appeared ripe and ready to spawn. One mature female with flowing eggs was netted in salt water at Hell's Gate on August 13. This specimen was far from fresh water and yet appeared ready to spawn. It is interesting to note that Weed (1934) recorded char taken from salt water on June 13 and 14, 1928, with free eggs in the oviducts. He states further that most specimens enter fresh water and spawn late in the fall while others of comparable size are apparently far from spawning condition at this time. Similar data were obtained in the present survey and probably indicate that char do not spawn every year after maturity is attained in this district. Weed observed spawning

Arctic char in one to two feet of water over small rounded rocks in rapids on October 28, 1928 and was informed by natives that the fish had been spawning for from two to four weeks.

Utilization by Eskimos

Arctic char are sought by the Eskimos along the west coast of Hudson Bay for food and dog feed and considerable quantities are required to satisfy their needs. The fish are captured by means of primitive hand lines, spears, rock traps and gill nets. Most of the fishing is carried on during the late summer when the char are congregated in the river mouths. Winter fishing is confined to fresh-water lakes. Winter-caught fish are frozen for use at later dates while the summer catch is used fresh or occasionally when char are obtained in numbers, some are salted and smoked for personal use later.

The Eskimos use most of the fish for food, including the head. The head is considered a delicacy and considerable time will be spent at a meal uncovering the last bit of meat hidden among the many bones of the head. Lake trout from the fresh-water lakes are also used as food but are not as desirable as the char, since in general they are thin and do not satisfy the Eskimos' apparently insatiable desire for fat.

An occasional white whale, or beluga, and seals are captured in the summer months to augment the supply of fish used to feed the dogs. In the winter months walrus meat is used for this purpose by those fortunate enough to obtain some of these animals. However, the basic dog food appears to be fish and principally char. No estimate of the average poundage required per dog per day was made, but it may be assumed that considerable quantities of char are used annually for this purpose.

Commercial Fishing

There was no indication obtained from this brief survey that Arctic char are available in sufficient quantities to warrant the establishment of a commercial fishery in the vicinity of Term Point. The test net catches, even at the river mouths, were too small to assure financial success for such an enterprise. It is possible that the run of char into the Wilson River and Pistol Bay was smaller than normal in 1948 and perhaps much larger catches would be made other years. This was verified by the Eskimos in the vicinity who stated that the run was small and consisted of smaller fish than had been taken previously. Reports were received of large runs of char in areas to the north where only occasional specimens are obtained most years.

Such reports indicate the need of additional information about the factors influencing the migration, spawning habits and population density of char before commercial fishing could be regulated on an annual sustained yield basis. At present the char appear to be available in insufficient quantities to supply the requirements of the local residents in this area.

A small commercial fishery for Arctic char was operated at Frobisher Bay on Baffin Island by the Shaw Steamship Company during the summer of 1948

(Grainger, 1948). Several types of gear were used and gill netting proved to give the best results. The catch, which was far from expectations, amounted to approximately 7,700 fish and these were either salted or canned for shipment. The data obtained from this experimental fishery should be of value in the establishment of similar fisheries throughout the Arctic if such are deemed advisable.

Future Investigations

Few scientific studies have been made on the Arctic char, which is one of the most important fishes in the economy of the Eskimos and other Arctic residents of Canada. A detailed investigation of the char in Hudson Bay should be carried out to augment the findings of previous preliminary surveys and to establish a sound basis for possible future exploitation.

A tagging programme, centred at one or two of the main streams flowing into the west side of Hudson Bay, followed by extensive netting, would supply data on the size of the population and the movement of this species both in fresh water and salt water. The age at maturity, length of the spawning cycle, the age at which the young first descend to the sea, rate of growth, feeding habits and factors influencing the return of the char to fresh-water streams should also be determined.

APPRECIATION

Mr. P. Zamick, who accompanied the author on this survey, proved to be a most willing assistant and his even disposition did much to make the trip enjoyable under the adverse conditions encountered.

Sincerest thanks are offered to Mr. Sam Voisey and his family at Term Point for their ready hospitality and assistance in the field and for the information they supplied about the habits of Arctic char in the region.

I would like to take this opportunity to express my thanks to Mr. F. Martin of Churchill, Manitoba, Mr. R. Hicks of Pistol Bay, N.W.T., and to the others whose willing advice and assistance aided in the survey.

SUMMARY

A preliminary investigation of Arctic char was carried out between August 12 and September 13, 1948, in the vicinity of Term Point, Northwest Territories, on the west coast of Hudson Bay.

A total of 216 fish was examined, including 64 char captured in salt water, 34 sea-run char taken in fresh water, 46 landlocked char and 49 lake trout, 11 tullibee, 9 round whitefish and 3 Arctic grayling taken in fresh water.

The length, weight and sex of each specimen were recorded, and scale samples were preserved for age determinations. Analyses of the stomach contents of 162 fish were made.

Nine char were tagged and released in the sea, with no recoveries made during the survey, but two were recaptured by Eskimos in 1949.

The sea-run char ranged from 4 to 22 years of age, from 12.5 to 32.5 inches in length and weighed from 0.75 to 16.0 pounds. The landlocked char were from

2 to 15 years old, from 6.25 to 15.25 inches long and weighed from 1 to 22 ounces.

The landlocked char matured at a much younger age than the sea-run specimens and showed a much slower rate of growth.

Evidence that the char spawn in fresh water on gravel and rubble bottoms during the fall and that the spawning cycle may be of more than one year's duration was obtained.

It was found that sea-run char do not feed, at least for some time, after arrival in fresh water. The sand-lance was the most important single food item of the char in the sea.

The Arctic char is of primary importance in the economy of the Eskimos and is used in quantities as food for themselves and for their dogs.

The results of this survey showed that char were not present in sufficient quantities to warrant the establishment of a commercial fishery in this region.

It is recommended that future investigations be carried out to provide data on the size of the char population in Hudson Bay, the movement of this species both in fresh and salt water, age at maturity, length of the spawning cycle, rate of growth, feeding habits and factors influencing the return of char to fresh water. These data could be used to establish a sound basis for possible future exploitation if it is proved that a surplus, over the requirements of the local residents, exists.

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Further Ostracoda of the Vancouver Island Region

By Verna Z. Smith
Atlantic Biological Station
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ABSTRACT

New distribution is given for *Conchoecia elegans* G. O. Sars and *C. spinirostris* C. Claus. Ten new species are described: *Philomedes carcharodonta, Pontocypris clemensi, Cythere alveolivalva, C. uncifalcata, Hemicythere bicarina, Cythereis serridentata, Loxoconcha dentarticula, L. tenuiungula, Paradoxostoma fraseri, P. striungulum. Cythereis obesa* Lucas is placed in *Hemicythere.*

This paper is a continuation of the recording of the forms of Ostracoda taken from the waters of the Gulf of Georgia in British Columbia during the summer of 1929 and 1930. The first records were published in 1931 in *Contributions to Canadian Biology and Fisheries* under the title of "Some Ostracoda of the Vancouver Island Region", by Verna Z. Lucas. Herein are described ten new species, and the female of *Philomedes longiseta* Juday (1907) which has not been previously recorded. Also are recorded new distributions for two species of *Conchoecia*: *C. elegans* G. O. Sars and *C. spinirostris* C. Claus.

As to the systematic arrangement of the Ostracoda, the classification of G. O. Sars (1928) has been followed in the sub-orders Myodocopa and Podocopa. I am not prepared now to uphold Skogsberg's (1928) classification of his genus *Cythereis*, as was done in 1931, and have therefore reclassified one species from the 1931 paper.

I should like to express my appreciation to Dr. A. W. H. Needler for permission to use laboratory and library facilities of the Atlantic Biological Station.

Philomedes carcharodonta n. sp. (Plate I, figs. 1-8, Plate II, figs. 1-6)

male: Left valve seen laterally (Plate I, fig. 2): dorsal and ventral margins evenly arched, the dorsal more widely than the ventral, the dorsal making a slight angle with the posterior margin. Anterior margin forms a small rostrum, rostral sinus being shallow. Surface finely granular with shallow, irregular depressions from which arise short hairs.

First antenna (Plate I, fig. 4): six-jointed with all setae and spines quite long. Sensory seta three times as long as the length of the fifth and sixth joints, basal portion of the seta being bulbous and covered densely with fine long setae, the distal portion of the seta bifurcate. The two apical setae very elongate, being three times the combined lengths of the second, third, fourth, fifth and sixth joints, annulated, with small setae placed regularly along their entire length.

Second antenna: exopodite (Plate II, fig. 3) three-jointed; the basal joint short and broad, second and third joints prolonged with the third reflexed upon

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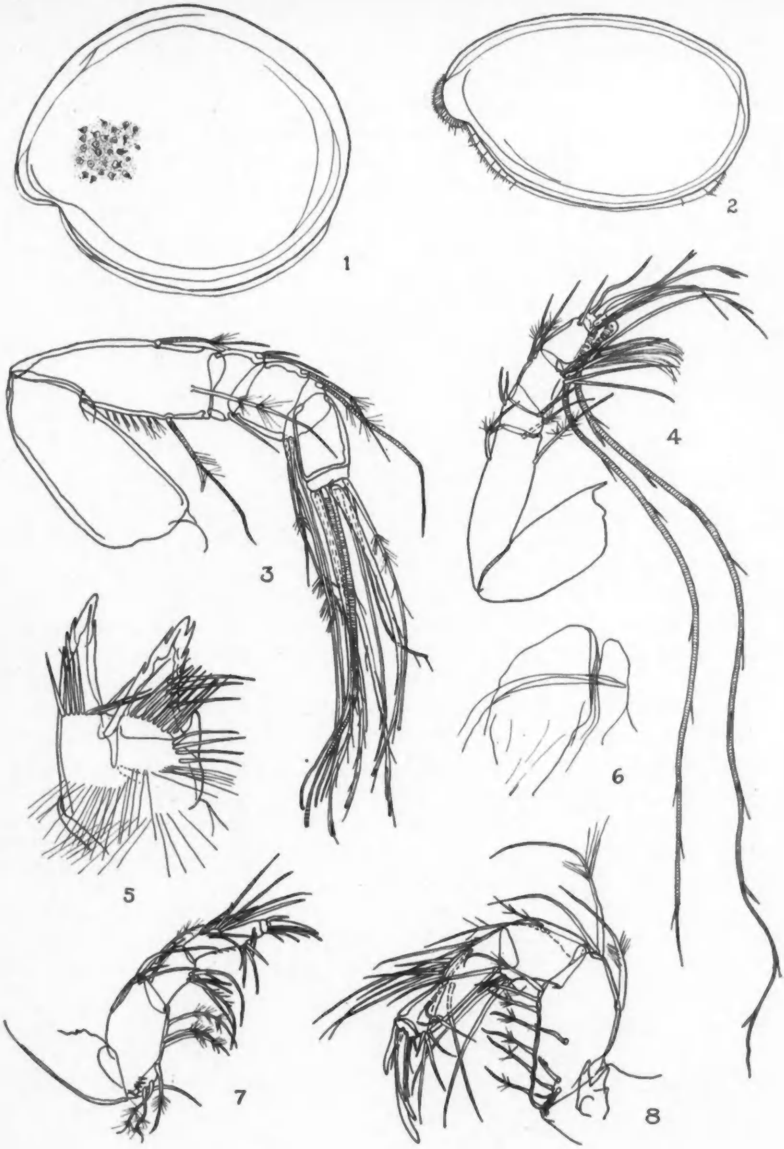

PLATE I. *Philomedes carcharodonta* n. sp.

1. ♀ left valve seen laterally ×18.
2. ♂ left valve seen laterally ×18.
3. ♀ first antenna ×50.
4. ♂ first antenna ×30.
5. ♀ mandibular teeth ×240.
6. ♂ copulatory appendage ×180.
7. ♂ mandible ×30.
8. ♀ mandible ×50.

the second. First joint bearing a cluster of six annulated setae at the base and one on the anterior margin; second joint with two large setae arising beside one another slightly posterior to the middle of the anterior margin. On the distal margin of the second joint a long annulated seta. Third joint blunt distally with flattened, toothed margin, bearing near distal end two small tooth-like annulated setae.

Mandible (Plate I, fig. 7): five jointed; distal three joints narrow, apical spines weak.

Seventh appendage (cleaning foot): eight annulated setae on the margins, four distal ones grouped two on each side.

Copulatory appendage (Plate I, fig. 6): bilobed.

Furca (Plate II, fig. 6): ten claws; the distal claws one, two, three and five being strong and heavily toothed with short stout setae in a line along the posterior margin; the fifth claw being one-third the length of the first; the other six claws small and weak, clothed with very fine setae.

Length: 2.09 mm.

FEMALE: Left valve seen laterally (Plate I, fig. 1): almost ovoid, rostrum more pronounced than in the male, sinus deeper. Surface same as in the male.

First antenna (Plate I, fig. 3): six-jointed; with the setae on all the joints longer than those in the male; apical setae as long as the combined lengths of the second, third, fourth, fifth and sixth joints.

Second antenna: exopodite (Plate II, fig. 2) two-jointed; basal joint with one distal seta and five setae in a group; distal joint tapered with one annulated seta on the distal margin, a long plumose seta arising from the middle of the anterior margin, being two and one-half times as long as the distal seta.

Mandible (Plate I, fig. 8): five-jointed with broad basal joints; three strong claws on the distal joint, two sub-equal and one shorter one which is one-third as long as the longest claw. Mandibular teeth (Plate I, fig. 5) with one small naked blunt tooth and two large teeth each set with numerous slender sharp teeth.

Seventh appendage (Plate II, fig. 1): ten plumose setae; the six distal ones grouped three on each side.

Furca (Plate II, fig. 5): ten marginal claws with the same general arrangement as in the male but of more robust character. Fifth claw being one half as long as the distal claw, fourth claw shorter and stouter than the proximal claws, proximal claws much longer and stouter than those of the male.

Length: 2.29 mm.

OCCURRENCE: 1934, Ganges Harbour, B.C., 5.5–7.3 m., (type locality).

REMARKS: The female was carrying large embryos in the brood pouch.

Philomedes longiseta Juday (Plate II, figs. 7-11)

Philomedes longiseta Juday, 1907, p. 139, pl. 18, figs. 13-15.

FEMALE: Right valve (Plate II, fig. 7) seen laterally: ovoid with the rounded rostrum projecting beyond the oval; inner margin of anterior rostral wall parallel to the longitudinal axis of the shell; marginal lip of rostrum transparent and deeply indented in sinus. Valves yellowish brown. Surface pitted with irregular

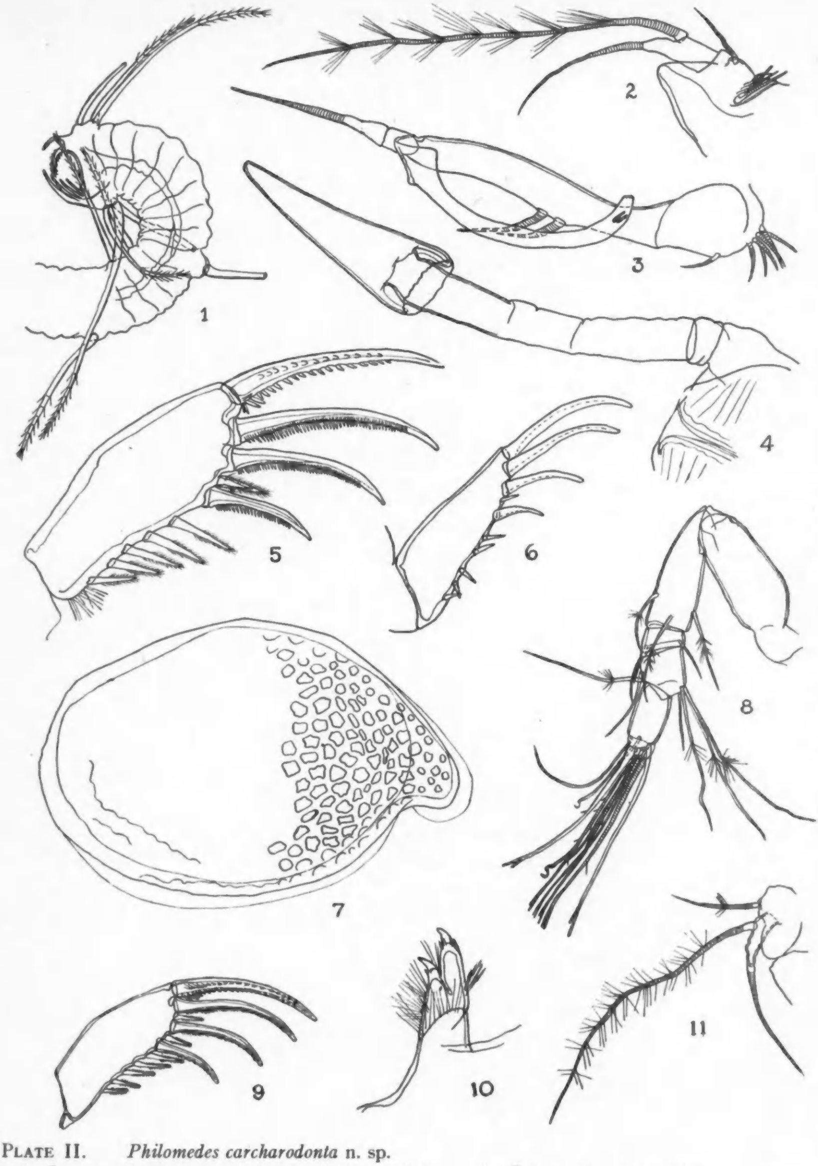

PLATE II. *Philomedes carcharodonta* n. sp.

1. ♀ seventh appendage (cleaning foot) ×70.
2. ♀ exopodite of second antenna ×70.
3. ♂ exopodite of second antenna ×70.
4. ♂ frontal organ ×180.
5. ♀ furca ×50.
6. ♂ furca ×30.

Philomedes longiseta Juday

7. ♀ right valve seen laterally ×22.
8. ♀ first antenna ×40.
9. ♀ furca ×40.
10. ♀ mandibular teeth ×180.
11. ♀ exopodite of second antenna ×70.

depressions which appear darker than the rest of the shell by transmitted light, the depressions with a few scattered hairs.

First antenna (Plate II, fig. 8): typical of genus.

Second antenna: exopodite (Plate II, fig. 11) two-jointed; basal joint bearing one plumose seta, distal joint with one distal seta and one long plumose seta situated on anterior margin one-third of the distance from the base of the joint, the plumose seta being six times as long as the distal joint.

Mandible: with the masticatory process (Plate II, fig. 10) deeply bifurcate, the processes having strong well-chitinized teeth at the tip.

Seventh appendage: having ten plumose setae, six being grouped three on each side at the distal end, the other four arranged two on each side further down the leg.

Furca (Plate II, fig. 9): eleven marginal claws; four strong toothed distal ones, five weak proximal ones which are approximately the same length, and two weak ones placed between the second and third, and the third and fourth distal claws respectively.

Length: 1.8 mm., height: 1.3 mm.

DISTRIBUTION: Coast of California, surface.

OCCURRENCE: 1929, Departure Bay, near Nanaimo, B.C., 20–30 m.; Cape Keppel, B.C., 30 m.; Brandon Island, near Nanaimo, B.C., 91 m.

REMARKS: In my paper (1931) a brief description of the female of *Philomedes longiseta* Juday (1907) was given but no mention was made of the fact that this was a new description, Juday having given only the male characters. Here are given more drawings and a more detailed description.

Conchoecia elegans Sars

Conchoecia elegans Sars, 1928, p. 22, pls. 11, 12.

Adult males and females were examined.

Length of female: 1.75 mm.

Length of male: 1.72 mm.

DISTRIBUTION: West coast of Sweden, British Isles, Arctic Sea, Atlantic Ocean.

OCCURRENCE: 1924, Station 1, B.C., 180-360 m., Snake Island, Nanaimo, B.C., Dredge, 36-145 m.

Conchoecia spinirostris Claus

Conchoecia spinirostris Claus, 1891, p. 56, pl. 1, figs. 1-12.

One male was examined, length: 1.98 mm.

DISTRIBUTION: Mediterranean Sea.

OCCURRENCE: 1929, Deserted Bay, B.C., 30 m.

Pontocypris clemensi n. sp. (Plate III, figs. 1-9)

FEMALE: Shell fragile with a glossy surface evenly marked by minute pits from which arise fine straight setae. Margins smooth. Trigonal in outline, narrowing posteriorly; greatest height in the anterior third. Length slightly more than twice the height. Right valve (Plate III, fig. 1) seen laterally; dorsal margin

PLATE III. *Pontocypris clemensi* n. sp.

1. ♀ right valve seen laterally ×50.
2. ♀ left valve seen laterally ×50.
3. ♀ ovary ×50.
4. ♀ furca ×215.
5. ♀ tip of penultimate claw of furca ×550.
6. ♀ second antenna ×215.
7. ♀ second walking leg ×215.
8. ♀ first antenna ×215.
9. ♀ maxilliped ×215.

smoothly arched anteriorly and posteriorly from the highest point; anterior margin evenly rounded, flattened dorsally, curving evenly ventrally; posterior margin evenly rounded flattening slightly ventrally before joining the ventral margin; ventral margin sinuated deeply in the centre; the valve dorsal to the sinuation bulges out laterally to form a pouch which folds down ventrally to cover the ventral sinuation. Inner duplicatures narrow, crossed by scattered pore-channels from which arise fine setae, the setae longer and more abundant on the anterior and posterior margins. Left valve (Plate III, fig. 2) seen laterally: the outline the same as the right valve except that the dorsal margin is slightly more curved posterior to the eye region. Eye comparatively large and prominent.

First antenna (Plate III, fig. 8): seven jointed, moderately sturdy. First joint twice as wide as the second joint with one long and two short setae on the distal margin; second joint slightly longer than the first but the same width with one seta on the anterior distal margin; third joint with one long seta on the anterior and one long seta on the posterior distal margin; fourth joint slightly shorter than half the length of the third joint with two long setae on the anterior and one short seta on the posterior distal margin; fifth, sixth and seventh joints progressively shorter and narrower than the preceding joint; fifth joint armed the same as the fourth; sixth joint with one long seta, one long stout seta and one short seta on the anterior and two short setae on the posterior distal margin; seventh joint with three setae extending beyond all the others, these being longer than the combined lengths of all the joints.

Second antenna (Plate III, fig. 6): six-jointed; stout with apical claws long and strong and swimming setae extending far beyond the apical claws. First joint longer than the second having on the posterior distal margin one annulated seta as long as the joint, and a sensitory seta, fragile, club-like, tapering distally, and on the anterior distal margin one seta. Second joint as long as the third with one seta on the posterior distal margin, being twice as long as the posterior margin on the second joint, and five swimming setae which are three times as long as the joint. Third joint with one stout seta on the posterior distal margin and two short fine setae situated one-seventh the way up from the anterior distal margin. Fourth joint slightly longer than one-fourth the length of the third, with two short setae of equal length on the posterior margin; one short stout seta and one claw one-half the length of the apical claws on the anterior distal margin. Fifth joint quite small with four long apical claws, curved at the tips, which are slightly longer than the combined lengths of the third and fourth joints, and one short claw which is one-half the length of the other four claws.

Maxilliped (Plate III, fig. 9): of normal Pontocyprid structure except that the second joint is bare and the small ultimate joint bears two long subequal claws and a very small bristle; the two claws being as long as the middle linear joint.

Second walking leg (Plate III, fig. 7): of normal Pontocyprid structure.

Ovaries (Plate III, fig. 3): forming a sigmoid curve between the lamellae of the valves in the posterior portion of the valves.

Furca (Plate III, fig. 4): tapering distally, very slightly exerted, armed with

two claws and four setae; one naked distal seta, short and rather coarse being one-half the length of the adjacent claw; two subequal claws, stout and armed at the tip with barbs (Plate III, fig. 5); one plumose seta, strong, the same length as the adjacent claw; two proximal setae separated from the other setae and claws, situated about the middle of the ramus, long, slender and ciliated only along the posterior margin, the distal one slightly longer than the claws, the proximal one nearly twice the length of the claws.

Length: 0.74 mm.

Male unknown.

OCCURRENCE: 1929, Departure Bay, near Nanaimo, B.C., tidal pools (type locality).

REMARKS: There is some doubt as to whether this species rightly belongs in the genus *Pontocypris*. Both Sars (1928) and Müller (1894) use the shape of the ovary as one key characteristic and according to that this species is a Pontocyprid; but Sars in giving the generic characters of the second antenna stresses the "apical claws long and slender, four in number, the foremost one being somewhat shorter than the others". Müller does not mention claws in either the generic or specific descriptions but shows in his figures (pl. 10, figs. 13, 16 and 17) that the second antenna has one short and three long apical claws. However Cushman (1906), in his description of the new species *Pontocypris edwardsi*, shows one short and four long terminal claws. This latter description is identical with the above described form which also has one short and four long claws. Sars also mentions in his generic description that the palps of the maxillipeds in the female have the "last joint small and tipped with a slender claw-like spine accompanied by 2 small bristles". On the ultimate joint of the maxilliped of the above described form there are two long subequal claws and a very small bristle. As this form seems to be allied most closely to the genus *Pontocypris*, it is placed under this genus until more forms have been studied or until the male has been examined.

Cythere alveolivalva n. sp. (Plate IV, figs. 1-10)

FEMALE: Left valve (Plate IV, fig. 2) seen laterally: greatest height in the middle, and slightly more than one-half the length; dorsal margin gently arched, terminating anteriorly and posteriorly with a slight angle; ventral margin deeply sinuated in the middle, meeting the posterior margin in a slight angle then curving dorsally; posterior margin with a slight angle in the middle; anterior margin obliquely rounded. Inner duplicatures broad, marginal zone well marked and crossed by distinct pore-channels. Surface pitted with approximately seventy large scattered pits.

First antenna (Plate IV, fig. 5): five-jointed; second joint equal in length to the combined lengths of the third and fourth joints; second joint bearing on the posterior distal margin a broad plumose seta which extends three-quarters of the way down the third joint; the stout claw on the ledge in the middle of the fourth joint extends just to the tip of the fifth joint; a distinct setiferous ledge on the anterior distal margin of the fourth joint between the two toothed claws bears one long seta and another just one-half as long.

PLATE IV. *Cythere alveolivalva* n. sp.

1. ♂ right valve seen laterally ×50.
2. ♀ left valve seen laterally ×50.
3. ♂ left valve seen laterally from the inside ×50.
4. ♀ mandibular teeth ×180.
5. ♀ first antenna ×85.
6. ♀ caudal lamella and posterior extremity of body ×180.
7. ♀ second antenna ×85.
8. ♀ third walking leg ×50.
9. ♂ copulatory appendage ×180.
10. ♀ mandibular palp ×85.

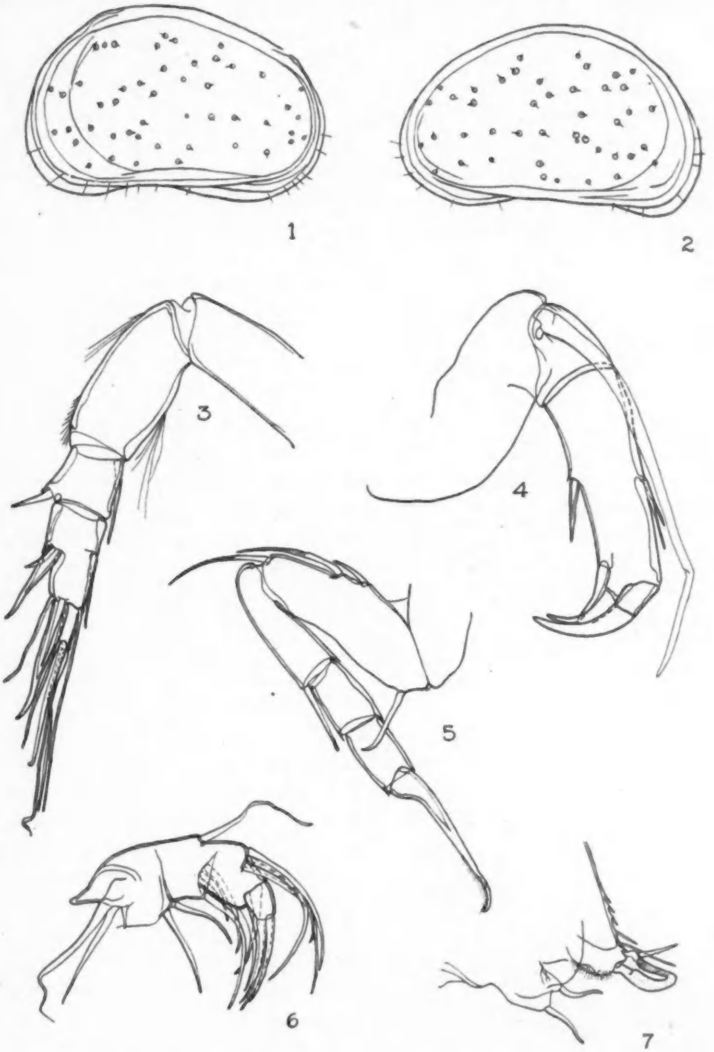

PLATE V. *Cythere uncifalcata* n. sp.

1. ♀ left valve seen laterally ×50.
2. ♀ right valve seen laterally ×50.
3. ♀ first antenna ×180.
4. ♀ second antenna ×180.
5. ♀ third walking leg ×180.
6. ♀ mandibular palp ×180.
7. ♀ caudal lamella and posterior extremity of body ×180.

Second antenna (Plate IV, fig. 7): four-jointed, broad and stout; flagellum extending not quite to the tip of the distal claws; the seta on the distal posterior margin of the second joint extending to the setiferous ledge of the third joint; this ledge bearing two subequal setae; anterior setiferous ledge of the third joint bearing two setae, one slightly longer than the longest seta on the opposite ledge, the other seta one-half as long. Terminal claws quite strong and blunt, distal one being three times the length of the anterior margin of the fourth joint.

Mandible (Plate IV, fig. 4): mandibular palp (Plate IV, fig. 10) with vibratory plate bearing one long and one short plumose seta, one very small slightly curved rudimentary seta, and a finger-shaped backward-pointing basal projection.

Third walking leg (Plate IV, fig. 8): combined lengths of the third and fourth joints much less than the length of the second joint; combined lengths of the second and third joints greater than the length of the first joint; seta on the distal margin of the second joint extending three-quarters of the way down the margin of the fourth joint. Posterior margin of the terminal claw quite straight but curved at the tip, distal half distinctly plumose on the inner anterior margin, claw being equal in length to the first joint.

Posterior extremity of the body (Plate IV, fig. 6): tipped by a highly chitinized curved spiniform process bearing on its posterior margin a seta which extends beyond the tip of the process, and at the base of the process numerous setae which extend to the tip of the other seta.

Caudal lamella (Plate IV, fig. 6): bearing two setae on the posterior margin and on a small knob-like process a lateral seta.

Length: 0.81 mm.

MALE: Valves (Plate IV, figs. 1, 3) and appendages similar to those of the female.

Copulatory appendage (Plate IV, fig. 9): almost square in general outline, basal portion projecting posteriorly in a long finger-like process, anteriorly into a blunt beak. This anterior process is quite different in shape in the right and left lamellae, the right being blunt, the left more produced and armed at the tip with a distinct hook.

Length: 0.75 mm.

OCCURRENCE: 1929, Horswell Point, Departure Bay, B.C., littoral zone in tide pools (type locality).

REMARKS: This form is closely related to *Cythere lutea* O. Fr. Müller, the living animals appearing quite similar. But on dissection the differences are readily seen, the most striking being the seventy pits on the valves, the strong setae on and dorsal to the chitinous process at the posterior tip of the body, and the three setae and process on the vibratory plate.

Cythere lutea O. F. Müller, *C. alveolivalva* n. sp. and the following new species, *C. uncifalcata,* were all found together in the same tide pools.

Cythere uncifalcata n. sp. (Plate V, figs. 1-7)

FEMALE: Left valve (Plate V, fig. 1): seen from the side, the greatest height

anterior to the middle, the height more than one-half the length. Dorsal margin gently curved meeting anterior and posterior margins in slight angles; ventral margin sinuated directly opposite greatest height, curving evenly to meet the posterior margin in a very slight angle; anterior margin obliquely rounded. Valves tapering slightly posteriorly. Surface with a few large scattered pits from each of which a single seta arises. Marginal zone narrow, crossed by a few pore-channels from which arise long fine setae. Inner duplicatures (Plate V, fig. 2) broad in anterior portion of the valve.

First antenna (Plate V, fig. 3): five-jointed, sturdy; combined lengths of the third and fourth joints equal to the length of the second joint; fifth joint narrow, one-half the length of the fourth joint; fourth joint rather broad bearing two claws, one on the setiferous ledge on the anterior margin, the other on the distal margin. These claws are of unusual shape being broad at the base but narrowing suddenly beyond the middle to form a narrow curved tip. One seta on the distal margin of the fifth joint strong, claw-like, curved at the tip.

Second antenna (Plate V, fig. 4): four-jointed, broad and powerful; setiferous ledge on the anterior margin of the third joint approximately in the middle, the setiferous ledge on the posterior margin not quite to the mid point; one small claw and one powerful claw on the distal margin of the third joint; fourth joint narrow and short with a short powerful claw. Flagellum large and well developed, reaching beyond the tip of the distal claws.

Mandible: mandibular palp (Plate V, fig. 6) sturdy and curved; vibratory plate with two long subequal setae and one short rudimentary seta arising from the base of a stout lobe of the plate.

Walking legs: four-jointed, short and stout; apical claws on the first and second legs curved, on the third leg (Plate V, fig. 5) straightened, narrowed, flattened but curved at the tip; the base of the claw quite broad, distal one-third clothed with fine setae. Third leg: combined lengths of the third and fourth joints of this leg equal to the length of the second joint; combined lengths of the second and third joints equal to the length of the first joint. Middle seta on the anterior margin of the first joint extending just beyond the knee, spine on the anterior distal margin of the second joint extending barely beyond the end of the third joint. The length of the distal claw equal to that of the anterior margin of the first joint.

Posterior extremity of the body (Plate V, fig. 7) produced into a heavily chitinized, thumb-shaped process bearing on its dorsal margin a seta which extends to the tip of the process. On the dorsal margin of the body just anterior to this process are five setae, the long seta next to the process extending almost to the tip of the process, the second seta only one-third as long as the first, then three small, barb-like ones forming small teeth.

Caudal lamella (Plate V, fig. 7): armed with two setae.

Length: 0.61 mm.

Male unknown.

OCCURRENCE: 1929, Horswell Point, Departure Bay, near Nanaimo, B.C., littoral zone among algae (type locality).

REMARKS: This form is more closely related to *Cythere alveolivalva* n. sp. than to *C. lutea* O. Fr. Müller. These three forms were all found together in the same locality at the same time of year.

Hemicythere bicarina n. sp. (Plate VI, figs. 1-8)

FEMALE: Left valve (Plate VI, fig. 1) seen laterally: higher in front than behind, greatest height slightly less than two-thirds of the length. Dorsal margin arched in the middle with sinuations just posterior to the anterior hinge tooth and just anterior to the posterior hinge tooth; anterior margin obliquely rounded, flattened dorsally in meeting the dorsal margin and forming a corner with the dorsal margin over the hinge tooth; ventral margin deeply sinuated in the middle; posterior margin with a definite projection ventrally which forms a smooth flat curve with the ventral margin; dorsally from this projection the posterior margin is sinuated forming a corner with the dorsal margin over the posterior hinge tooth. Right valve smaller than the left, ventral margin not so deeply sinuated, posterior projection more pronounced forming a sharper corner with the ventral and posterior margins. Valves white; heavily calcareous; with large irregular pits whose walls form two slightly elevated ridges running anterio-posteriorly, one above the other, the ventral one starting in the middle of the anterior projection fades out in the posterior half of the valve, the dorsal one starts approximately in the middle of the valve curves dorsally to end just ventral to the posterior hinge tooth. Edges of the valves smooth. Duplicatures quite broad and crossed by numerous pore-channels from which arise very broad setae that taper to fine points.

First antenna (Plate VI, fig. 2): five-jointed; first and second joints subequal, second joint bearing a seta on the posterior distal margin; third joint slightly more than one-third the length of the second with a straight claw on the anterior distal margin; fourth joint twice as long as the third with one seta and one claw on the setiferous ledge, and one seta and one strong curved claw on the anterior distal margin; fifth joint slightly shorter than and about one-seventh the width of the third joint, with one heavy curved claw extending beyond the distal claw of the fourth joint, one seta longer than the claw, one seta equal to the length of the claw and one seta shorter than the claw.

Second antenna (Plate VI, fig. 4): four-jointed; first and third joints subequal; second joint one-third the length of the third joint with a plumose seta on the posterior distal margin extending to the tip of the third joint; third joint with a setiferous ledge on the middle of the posterior margin bearing one strong pectinated bristle extending to the tip of the joint, one naked seta shorter than the bristle and one frail club-shaped seta one-half the length of the naked seta; on the anterior margin a setiferous ledge with two long setae, one extending almost to the tip of the distal claws, near the posterior distal end one short seta; fourth joint small, two equal strong curved claws on the posterior margin and one very stout claw on the distal margin longer than the other two claws. Flagellum short, extending to the posterior setiferous ledge of the third joint.

Mandible: Vibratory plate with one plumose seta and a small bulbous hook;

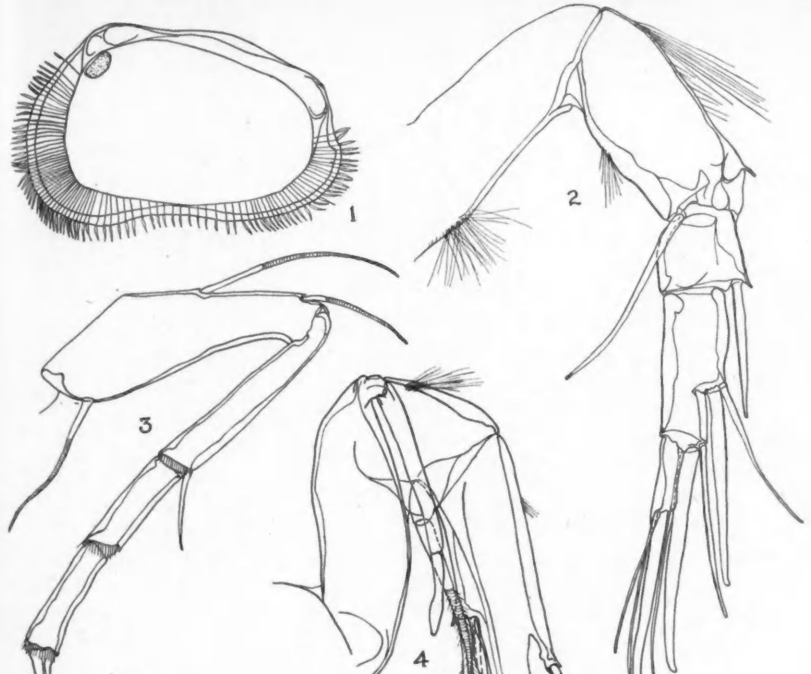

PLATE VI. *Hemicythere bicarina* n. sp.

1. ♀ left valve seen laterally ×50.
2. ♀ first antenna ×215.
3. ♀ third walking leg ×215.
4. ♀ second antenna ×215.
5. ♀ caudal lamella ×180.
6. ♂ copulatory appendage ×215.
7. ♀ mandibular teeth ×215.
8. ♀ mandibular palp ×215.

masticatory portion (mandibular teeth) (Plate VI, fig. 7) coarse with two rather long bristles between the first and second teeth. End joint of the palp (Plate VI, fig. 8) medium stout, not curved.

Third leg (Plate VI, fig. 3): moderately strong with a long curved apical claw. Combined lengths of the third and fourth joints slightly longer than the apical claw and slightly shorter than the second joint; distal margins of the second, third and fourth joints densely ciliated.

Caudal lamella (Plate VI, fig. 5): small with two plumose setae at the tip.

Length: 0.73 mm.

MALE: Valves having the same general shape as that of the female but more pointed posteriorly.

Second antenna: flagellum distinctly three-jointed, reaching beyond the distal tip of the end claws.

Copulatory appendage (Plate VI, fig. 6): roughly triangular in outline, being produced anteriorly into a blunt beak-like projection.

Length: 0.68 mm.

OCCURRENCE: 1929, Horswell Point, Departure Bay near Nanaimo, B.C., tidal pools (type locality). Gabriola Pass, B.C., on *Laminaria* holdfasts.

REMARKS: This species is closely related to *Cythereis iganderssoni* Skogsberg (1928), which, according to the generic classification of Sars and Müller, would belong to the genus *Hemicythere*.

Hemicythere obesa (Lucas)

Cythereis obesa Lucas, 1931, Contr. Can. Biol. and Fish., 6 (17), 8-9, pl. 3.

REMARKS: On closer examination of this species it was found to possess all the generic characteristics of *Hemicythere* as given by G. O. Sars (1928) and therefore is referred to that genus.

Cythereis serridentata n. sp. (Plate VII, figs. 1-6)

FEMALE: Shell heavy, white, calcareous. Right valve (Plate VII, fig. 2) seen laterally: greatest height just anterior to the middle, height being seven-tenths of the length. Dorsal margin evenly arched, a little more flattened posteriorly than anteriorly; ventral margin sinuated slightly anterior to the middle; anterior and posterior margins evenly rounded; on the ventral portion of the anterior margin and extending onto the ventral margin twelve protuberances tufted with setae; on the postero-ventral margin six small tufted protuberances. Inner duplicatures of moderate width. Hinge teeth small. Surface of shell with scattered pits.

First antenna (Plate VII, fig. 4): six-jointed, of usual Cythereid character. The annulated seta on the posterior distal margin of the second joint extending well beyond the tip of the sixth joint.

Second antenna (Plate VII, fig. 1): of more sturdy structure than most species of this genus. Four-jointed; first and third joints subequal, fourth joint two-thirds the length of the second joint. Setiferous ledge on the anterior margin of the third joint two-sevenths of the distance from the distal margin; setiferous ledge on the posterior margin two-fifths of the distance from the distal margin.

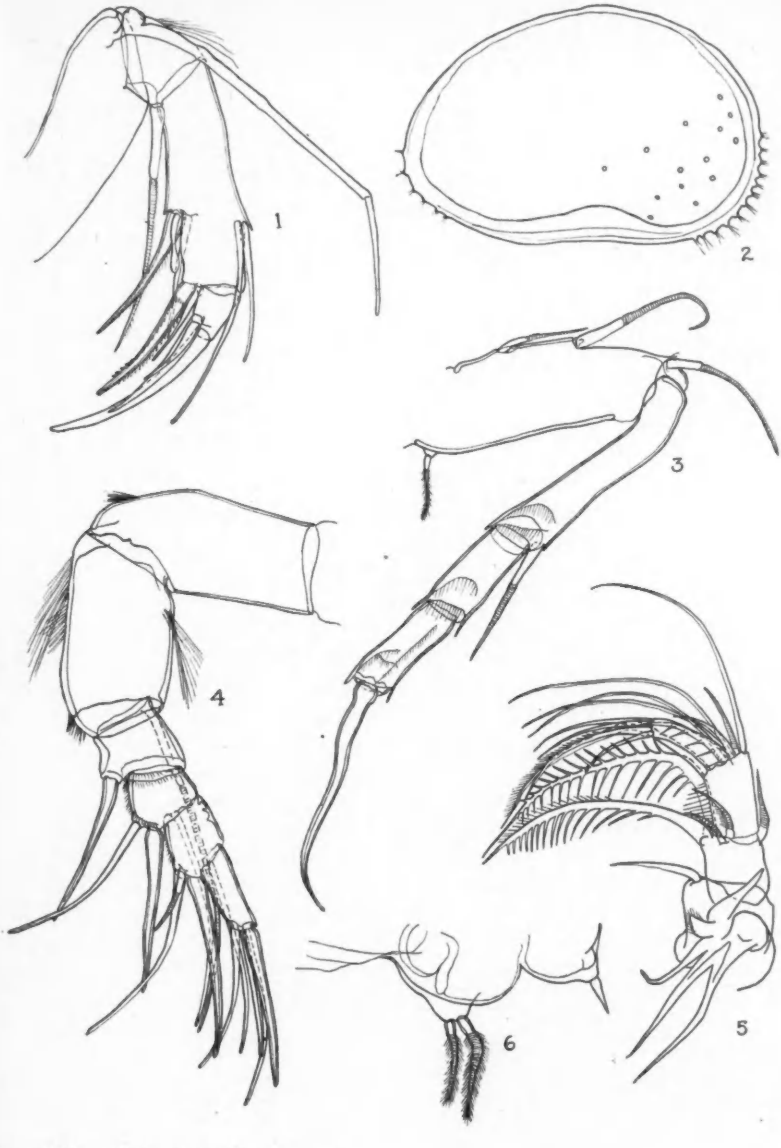

PLATE VII. *Cythereis serridentata* n. sp.

1. ♀ second antenna ×180.
2. ♀ right valve seen laterally ×50.
3. ♀ third walking leg ×180.
4. ♀ first antenna ×180.
5. ♀ mandibular palp ×180.
6. ♀ caudal lamella and posterior extremity of body ×180.

Of the three claws on the distal margin of the fourth joint the second and third are approximately two and three times the length of the first. A strong claw on the posterior distal margin of the third joint with a double row of strong teeth (a distinct specific character).

Mandible: mandibular palp (Plate VII, fig. 5) of sturdy construction having on the posterior distal margin of the second joint two strong plumose setae longer than the apical setae; only one seta on the posterior distal margin of the first joint. Vibratory plate of usual structure—five setae, one rudimentary.

Third walking leg (Plate VII, fig. 3): strong and not particularly elongated; with apical claws as long as the second joint. Apical claws with an "S" curve barely noticeable in the first leg, more discernible in the second, and very evident in the third leg.

Caudal lamella (Plate VII, fig. 6): with two plumose setae at the tip.

Length: 0.76 mm.

Male unknown.

OCCURRENCE: 1930, Phillip's Arm, B.C., dredge, 30.5 m., (type locality).

Loxoconcha dentarticula n. sp. (Plate VIII, figs. 1-7)

MALE: Shell (Plate VIII, figs. 5, 6) fragile; pellucid; with the greatest height well forward at the anterior hinge tooth, height greater than one-half the length. Dorsal and ventral margins nearly parallel, dorsal margin straight between the hinge teeth forming definite corners with the anterior and posterior margins. Posterior margin evenly curved, somewhat compressed ventrally. Anterior margin obliquely rounded forming a greater curve with the ventral margin than with the dorsal margin. Ventral margin sinuated anterior to the middle of the valve. Edges of the valves thin with scattered, long, irregular, fine hairs. Surface (Plate VIII, fig. 4) with irregular impressed pits and knob-like tubercles.

First antenna (Plate VIII, fig. 2): six-jointed; distal joint rather prolonged. First joint longer and wider than the second; second joint with plumose seta on the posterior distal margin extending to the end of the fourth joint; third joint about one-third the length of the second with a seta on the anterior distal margin extending nearly to the end of the fifth joint; fourth joint slightly longer and narrower than the third with a seta on the anterior distal margin and a very long seta on the posterior distal margin extending to the tip of the seta on the sixth joint; fifth joint longer than the fourth with three long setae on the anterior distal margin and one long seta on the posterior distal margin; sixth joint twice as long as the fifth with four long setae at the distal end. The articulation between the fourth and fifth joints is very faint.

Second antenna (Plate VIII, fig. 1): four-jointed; first joint two and one-half times the length of the second; flagellum articulating in two places and extending to the tip of the distal claws; second joint with plumose seta on the posterior margin extending beyond the setiferous ledge on the posterior margin of the third joint; third joint greater than four times the length of the second with the anterior setiferous ledge proximal to the middle of the anterior margin, the posterior setiferous ledge being slightly distal to the middle of the posterior

PLATE VIII. *Loxoconcha dentarticula* n. sp.

1. ♂ second antenna ×215.
2. ♂ first antenna ×215.
3. ♂ third walking leg ×215.
4. ♂ detail of shell sculpture ×550.
5. ♂ right valve seen laterally ×50.
6. ♂ left valve seen laterally ×50.
7. ♂ copulatory appendage ×215.

margin; the anterior ledge with one long and one short seta; the posterior ledge with one seta and one claw-like seta subequal, and one club-ended seta extending to the tip of the joint; a heavy seta arising on the posterior margin near the distal end of the joint; on the posterior distal margin a curved claw; fourth joint small and narrow, three times as long as wide, with a curved claw at the distal end; distal claws equal in length and three and one-half times the length of the fourth joint. Outstanding feature is the extreme smallness of this appendage in proportion to the rest of the appendages.

Third walking leg (Plate VIII, fig. 3): four-jointed; second joint greater than the combined lengths of the third and fourth joints; third joint small with the posterior margin notched to form small teeth (a distinct specific characteristic); distal claw equal in length to the second joint.

Copulatory appendage (Plate VIII, fig. 7): basal portion roughly triangular, terminal portion frail and semilunar with two heavily chitinized bars forming an unequal armed "Y".

Length: 0.66 mm.

Female unknown.

OCCURRENCE: 1930, Phillip's Arm, B.C., on algae (type locality).

Loxoconcha tenuiungula n. sp. (Plate IX, figs. 1-6)

FEMALE: Left valve (Plate IX, figs. 2, 5) seen laterally: rhomboid in outline; the greatest height at the anterior hinge tooth being slightly greater than three-fifths of the length; dorsal margin almost straight curving posteriorly to meet the posterior margin in a slight angle, immediately ventral to the angle a small indentation; ventral margin slightly sinuated, curving dorsally to meet the posterior margin in an even curve; anterior margin produced obliquely, evenly arched; hinges small but distinct. Shell thin and pellucid; surface with shallow scattered hollows, the centres of which have small pits giving rise to short setae.

First antenna (Plate IX, fig. 1): six-jointed; the combined lengths of the third, fourth and fifth joints equal in length to that of the second joint; combined lengths of the third and fourth joints equal to the length of the sixth joint. Seta on the posterio-distal margin of the second joint plumose, other setae of the limb being bare. The long distal seta equal in length to the combined lengths of the second, third, fourth and fifth joints. The third, fourth and fifth joints each bearing on their anterio-distal margins a strong almost claw-like seta.

Second antenna (Plate IX, fig. 3): four-jointed; with well developed flagellum. Length of the posterior margin of the third joint equal to greatest diagonal length of the first joint. Setiferous ledge on the anterior margin of the third joint a little more than one-third the way down the margin, bearing one seta; posterior setiferous ledge of the joint a little more than one-half way down the margin, bearing three setae, one of them strong. On the distal margin of the third joint a short heavy seta and a strong curved claw. Fourth joint very small bearing a strong curved claw slightly shorter than the other claw.

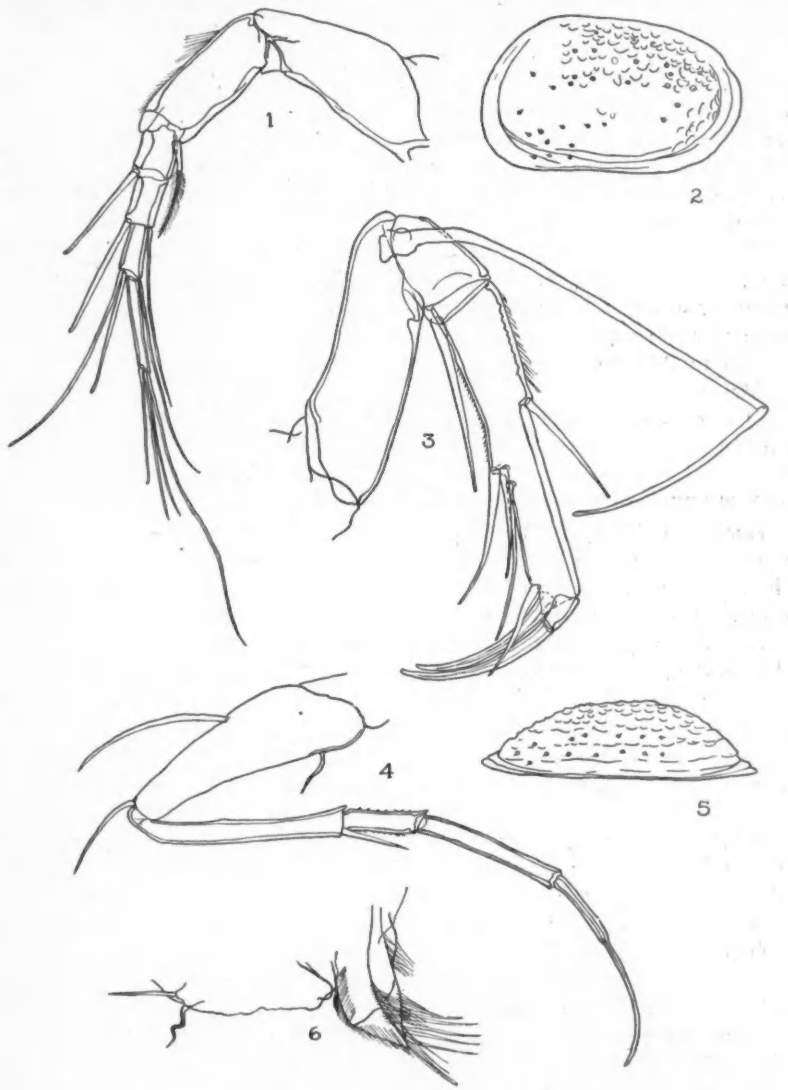

PLATE IX. *Loxoconcha tenuiungula* n. sp.

1. ♀ first antenna ×300.
2. ♀ left valve seen laterally ×50.
3. ♀ second antenna ×300.
4. ♀ third walking leg ×180.
5. ♀ left valve seen ventrally ×50.
6. ♀ caudal lamella and posterior extremity of body ×300.

Mandible: the penultimate joint of the mandibular palp widens considerably just about the middle.

Third leg (Plate IX, fig. 4): four-jointed; long and slender; the fourth joint approximately two-thirds the length of the second joint and twice as long as the third joint; the anterior and posterior margins of the third joint armed with small regularly spaced setae (tooth-like); terminal claw as long as the second joint, the basal third of the claw heavy, abruptly narrowing into the slender apical two-thirds of the claw. The shape of this claw is an outstanding diagnostic feature of this species.

Posterior portion of the body (Plate IX, fig. 6) produced into a process thickly clothed in long setae, some of which along the dorsal margin are strong and evenly spaced. Caudal lamella (Plate IX, fig. 6) with a knob-like prominence carrying two divergent setae.

Length: 0.59 mm.

Male unknown.

OCCURRENCE: 1930, Phillip's Arm, B.C., littoral zone among algae (type locality).

Paradoxostoma fraseri n. sp. (Plate X, figs. 1-10)

FEMALE: Left valve (Plate X, fig. 2) seen laterally: greatest height slightly posterior to the middle and less than one half the length. Dorsal margin evenly arched, joining anterior and posterior margins smoothly; anterior and posterior margins almost identically pointed, the anterior curving more acutely on joining the ventral margin; the ventral margin sinuated in the anterior half, boldly arched in the posterior half. Valves roughly elliptical in outline. Eye distinct and large. Inner duplicatures quite narrow, distinct; a few pore-channels in the anterior and posterior ventral portions with fine setae.

First antenna (Plate X, fig. 6): six-jointed, slender; second and third joints subequal, each being slightly longer than the first and fourth joints which are in themselves subequal; combined lengths of the fifth and sixth joints exactly one-half the length of the third joint. Seta on the anterior distal margin of the third joint two-thirds the length of the fourth joint; seta on the posterior distal margin of the fourth joint twice as long as the fifth joint; seta on the anterior distal margin longer than the fifth joint; the two distal setae of the fifth joints subequal and slightly longer than three times the length of the sixth joint; two distal setae on the sixth joint—one slightly longer than the other—approximately equal in length to the distal setae of the fifth joint.

Second antenna (Plate X, fig. 5): four-jointed; penultimate joint undivided. First and third joints subequal; fourth joint slightly shorter than the third. Flagellum distinctly three-jointed, extending to the tip of the distal claw. Plumose seta on the posterior distal margin of the second joint slightly longer than one-half the length of the third joint. Setiferous ledge on the anterior margin of the third joint two-thirds the distance from the proximal margin; setiferous ledge on the posterior margin slightly more than one-half the way from the proximal margin, each ledge bearing one strong seta. Seta on the posterior distal margin of the third

PLATE X. *Paradoxostoma fraseri* n. sp.

1. ♀ oral cone with sucking disk ×215.
2. ♀ whole mount from left side ×50.
3. ♀ mandible ×215.
4. ♀ maxilla ×215.
5. ♀ second antenna ×215.
6. ♀ first antenna ×215.
7. ♀ first walking leg, dextral, showing spine from sinistral leg of same pair ×215.
8. ♀ posterior extremity of body from right side ×215.
9. ♀ setae under caudal lamella ×215
10. ♀ caudal lamella ×215.

joint strong and as long as the fourth joint; one seta and one claw on the distal margin of the fourth joint, the seta being slightly less than one-half the length of the claw, the claw very strong, curved at the tip, being one and one-half the length of the fourth joint.

Oral cone (Plate X, fig. 1): sides of the cone almost straight forming sharp corners on either side of the disk; sucking disk protuberant, funnel-shaped.

Mandible (Plate X, fig. 3): exceedingly long and slender; palp distinctly three-jointed with the indication of a fourth articulation at the distal end.

Maxilla (Plate X, fig. 4): with three masticatory lobes, one small with two strong, bristle-like setae distally, the other two extending almost to the ends of the fore-mentioned setae, each with four long delicate setae. Vibratory plate with two deflexed setae at the base. Palp wanting.

Walking legs: moderately slender with long strong apical claws, setae also long and strong. First leg (Plate X, fig. 7): four-jointed; combined lengths of the second, third and fourth joints four-fifths the length of the first joint; third joint one-half the length of the second joint; fourth joint two-thirds the length of the second joint; apical claw as long as the second joint. Distal seta of the first joint very wide and robust being twice the length of the fourth joint; distal seta of the second joint reaching to the distal margin of the third joint. This seta differs on the sinistral and dextral joints of the second and third pair of legs, the seta on the sinistral joint being shorter by half and more bulbous than that on the dextral joint. The fourth joint and the distal claw of the third leg are bare.

Caudal lamella (Plate X, figs. 9, 10): not particularly small, produced posteriorly into a slightly upcurved projection; four very small fine setae posterior to the lamella. Posterior portion of the body (Plate X, fig. 8) produced to a narrow, sharp projection.

Length: 0.73 mm.

Male unknown.

OCCURENCE: 1930, Brandon Island, near Nanaimo, B.C., 91 m. (type locality).

REMARKS: Specimens were found caught in the surface tension of water being used to wash material dredged from the bottom of the bay.

The fact that this form has a well-developed sucking disk on the oral cone would place it in the subfamily Paradoxostominae. On the other hand, the undivided penultimate joint of the second antenna, the greater strength of the distal claws of the second antenna and walking legs, the much attenuated length of the mandible and articulation of the palp, the pointed caudal lamella, and the shape of the posterior portion of the body are not found in any of the genera in this subfamily. In reviewing the characteristics of this new form, it seems to resemble most closely the genus *Paradoxostoma*. The resemblance, however, is in exaggerated degree: the sucking disk more prominent, the distal claws stronger, the mandible longer and narrower, etc. These differences are great enough to make this form the type of a new genus. However, until the male and further females have been found and studied, this new species will be designated as *Paradoxostoma fraseri*.

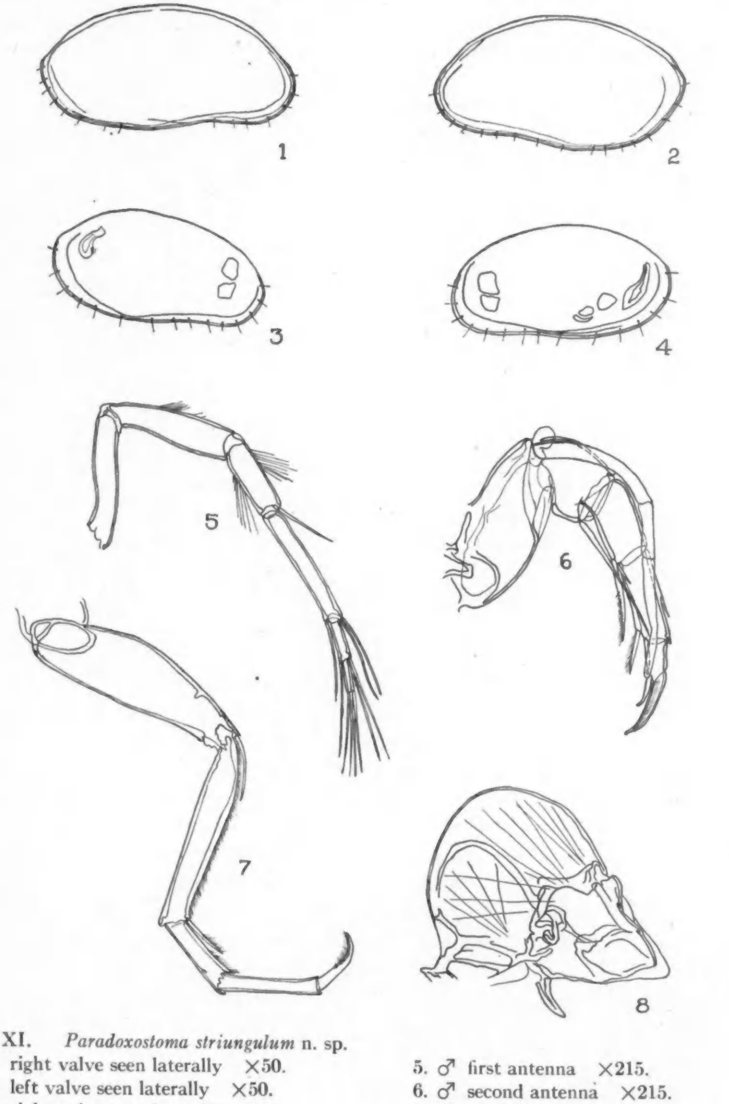

PLATE XI. *Paradoxostoma striungulum* n. sp.

1. ♀ right valve seen laterally ×50.
2. ♀ left valve seen laterally ×50.
3. ♂ right valve seen laterally ×50.
4. ♂ left valve seen laterally ×50.
5. ♂ first antenna ×215.
6. ♂ second antenna ×215.
7. ♂ third walking leg ×215.
8. ♂ copulatory appendage ×215.

Paradoxostoma striungulum n. sp. (Plate XI, figs. 1-8)

MALE: Shell (Plate XI, figs. 3, 4) fragile; pellucid; pale yellow; setae on the margins sparse, on the surface very few. Right valve (Plate XI, fig. 3) seen laterally: oval in outline, greatest height posterior to the middle being one-half that of the length; dorsal margin evenly arched, flattening posteriorly into a straight line and meeting the posterior margin in a slight angle; ventral margin slightly sinuated in the anterior third, evenly curving into the posterior margin; anterior margin boldly rounded smoothly meeting the dorsal and ventral margins.

First antenna (Plate XI, fig. 5): six-jointed; slender, of usual Paradoxostomal structure; fourth and fifth joints armed with two equal setae on the anterior distal margin and one seta on the posterior distal margin; sixth joint with four setae on the distal margin extending slightly beyond the setae of the fifth joint.

Second antenna (Plate XI, fig. 6): rather stouter than the usual Paradoxostomal structure; five-jointed; first and second joints broad; third, fourth and fifth joints narrow and tapering distally; second joint one-half the length of the first with a seta on the posterior distal margin extending almost to the end of the fourth joint; third joint the same length as the second joint with one very small seta and one ciliated seta on the posterior distal margin; fourth joint longer than the third joint with one ciliated seta near the posterior distal margin and one small seta in the middle of the anterior margin; fifth joint one-half the length of the third joint with one short curved claw and one very stout ciliated curved claw on the distal margin. This claw is of unusual structure being very broad and stout for most of its length but as it starts to curve at the distal end it narrows and straightens abruptly to form a sharp straight naked tip (diagnostic feature). Flagellum articulating in two places, extending to the distal end of the fifth joint.

Third walking leg (Plate XI, fig. 7): four-jointed; first and second joints nearly equal in length, the first being slightly longer; third joint slightly more than one-third the length of the second; fourth joint one-half the length of the second; first joint bearing a seta on the anterior distal margin, second joint bearing a ciliated seta on the anterior distal margin which is one-half the length of the fourth joint; the anterior margin of the second joint densely plumose along the entire length, the anterior margin of the third joint densely plumose along the distal one-half of the margin; end claw small, being two-thirds the length of the fourth joint, straight at the base but curved and ciliated at the distal end.

Copulatory appendage (Plate XI, fig. 8): basal portion irregularly oval, produced terminally into a triangular projection.

Length: 0.57 mm.

FEMALE: Shell (Plate XI, figs. 1, 2): larger than but with the same outline as that of the male. Height greater than one-half the length.

The other appendages are the same as those of the male.

Length: 0.64 mm.

OCCURRENCE: 1930, Departure Bay, near Nanaimo, B.C., on *Obelia* near the surface of the water (type locality).

Below is a list of the names of the new species described in this paper. The names were chosen in most cases to bring out the salient feature or features of each species. Following the names are short descriptions of the key characteristic of each, the literal translation of the specific name being placed, where possible, in quotation marks.

Philomedes carcharodonta
sharp "triangular teeth with serrated edges" on the mandibular teeth.
Pontocypris clemensi (in honour of Dr. W. A. Clemens, Head of the Department of Zoology, University of British Columbia)
five apical claws of the second antenna, and the palps of the maxilliped
Cythere alveolivalva
"pitted shell"
Cythere uncifalcata
"hooked" distal "claw" on the third walking leg
Hemicythere bicarina
"two ridges" on the valves
Cythereis serridentata
"saw teeth" on the claw of the penultimate joint of the second antenna
Loxoconcha dentarticula
"teeth" on the "small joint" of the third walking leg
Loxoconcha tenuiungula
"thin claw" on the third walking leg
Paradoxostoma fraseri (in memory of the late Dr. C. McLean Fraser, Professor Emeritus, Department of Zoology, University of British Columbia)
undivided second antenna
Paradoxostoma striungulum
curved "claw" of the second antenna "with striations"

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Currents and Net Transport in Loudoun Channel, April 1950

By L. A. E. Doe

Pacific Oceanographic Group, Pacific Biological Station, Nanaimo, B.C.

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ABSTRACT

An investigation of the Loudoun Channel area of Barkley Sound was carried out in April 1950 to determine the currents, net transports, and oceanographic conditions in the vicinity of the herring spawning grounds. Currents were measured at anchor stations by means of captive floats. Serial observations of salinity and temperature were made both at the anchor stations and in synoptic surveys of the region. Evidence was found that a significant change in the pattern of flow occurred between the earlier and later parts of the month which appeared to be associated with a sudden increase in the rate of discharge of the Somas River in nearby Alberni Inlet.

INTRODUCTION

An investigation of the Loudoun Channel area of Barkley Sound (Figure 1) was carried out in April 1950, to determine the currents, net transport of water, and oceanographic conditions in the vicinity of the herring spawning grounds.

Loudoun Channel is the northwestern section of Barkley Sound, separated from Imperial Eagle Channel by the Broken Group, a cluster of islands and reefs (Figure 1). Depths between shoals in Loudoun Channel range from 20 to 30 fathoms.

The Maggie and the Toquart are the largest rivers emptying directly into the channel but there is evidence that fresh water is contributed from Alberni Inlet by way of Imperial Eagle Channel and the passages through the Broken Group.

Tully (1949, MS) has discussed the dispersal of fresh water in the sea in a two-dimensional system from a single source and has shown that the fresh water moves persistently seaward over the underlying ocean water, forming a brackish upper zone in which the salinity continuously increases with depth and distance seaward along the line of flow. He concludes that the seaward transport of ocean water (mixed with fresh water) in the upper zone is compensated by a counter (in-) flow of ocean water in a lower zone.

While these principles undoubtedly apply in Loudoun Channel, there is a mingling of the fresh water outflow from the several sources and the continuity with each is not readily apparent. Furthermore it is not necessary that the counter-flow enter Loudoun Channel beneath the upper zone, since it could occur on one side of the channel while the outflow proceeds on the other, or be supplied through the Broken Group and move seaward with the upper zone.

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PROGRAMME AND METHODS OF OBSERVATION

Currents were measured from an anchored boat at 0, 3, 5, and 10 fathoms depth every 1½ hours throughout a tidal day (25 hours) at each of eight positions (anchor stations). It was originally planned to repeat every station but this was completed in only one instance. All other cases were frustrated by weather on either the first or second attempt. A summary of the actual time spent on each station is given in Table I.

TABLE I. Summary of hours and observations at each station. Unless otherwise indicated, reference is to anchor stations.

Station No.	Date	Hours occupied	Number of Measurements at each depth	Remarks
1–9	4	—	—	Serial casts and BT's (Synoptic Survey)
9	5–6	25	—	Using drift-pole
8	6–7	25	—	—not comparable
2	7–8	13½	8	Boat broke moorings
10–14	8	—	—	Serial casts and BT's
6	8–9	25	14	Complete
4	9–10	15	8	Blown off station
8	10	5	2	Blown off station
	11	—	—	Southeast gale.
15	12–13	25	16	Complete
	14–16	—	—	Southeast gales.
16–22	17	—	—	Serial cast and BT's, Imperial Eagle Channel
5	17–18	25	15	Complete
24	19–20	25	17	Complete
23	20	5½	3	Blown off station
25	20–21	25	15	Complete
8	21–22	25	16	Complete
23	22–23	25	17	Complete
24	24–25	25	14	Complete
26–39	25–26	25	—	Serial casts and BT's (Synoptic Survey)
39	25–26	24	14	Complete

The drift-pole technique, a modification of the traditional chip log (Marmer, 1926), was tried, but proved unsuitable for this investigation because the current velocity varied markedly with depth through the top 18 feet. The pole was replaced by a current drag made from a pair of sheet-metal vanes, 18 by 24 inches, set at right angles and suspended on a cod line which passed through the centre of an ellipsoidal buoy. Eyes were tied in the line at intervals of one fathom, so that by putting a shackle into the appropriate eye the vanes could be set at any specified depth from the surface to 10 fathoms. The mean depth of the vanes when set for "surface" observations was approximately 1 foot.

Considerable difficulty was experienced because the ship (C.N.A.V. "Ehkoli", an 84-foot seine boat adapted for oceanographic research) did not lie steady

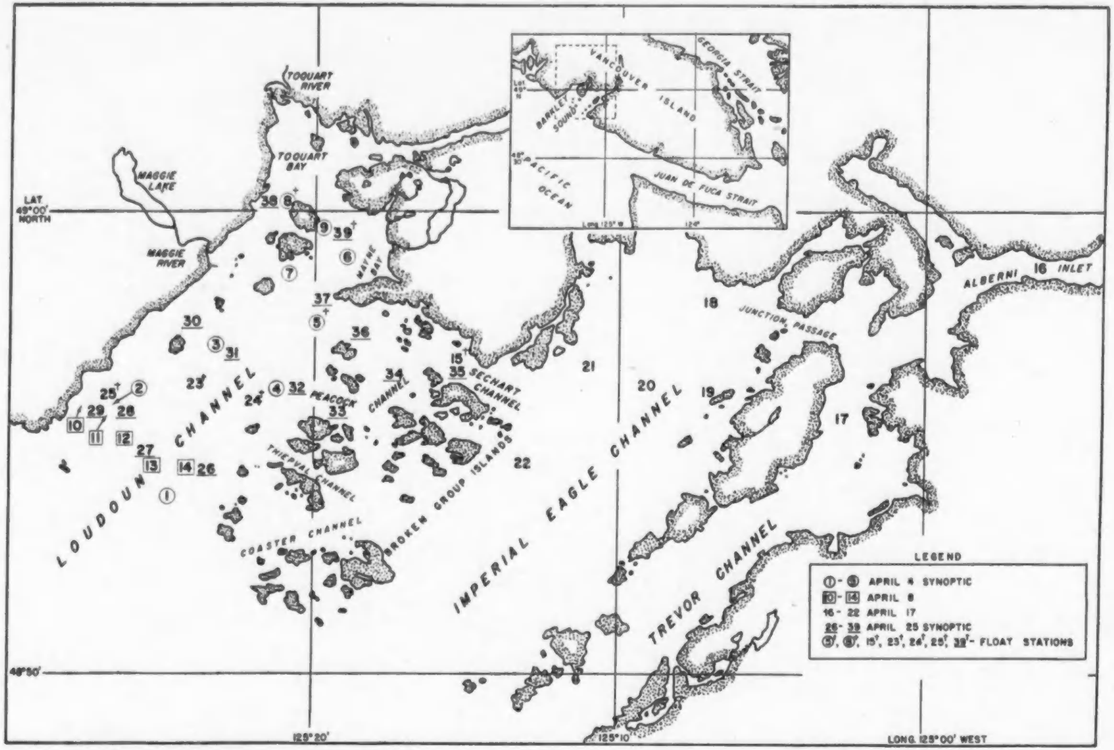

FIGURE 1. Barkley Sound, Vancouver Island. The numbers indicate the positions of serial stations and 25-hour anchor (float) stations occupied during the survey of April 1950. Dates are given in Table I.

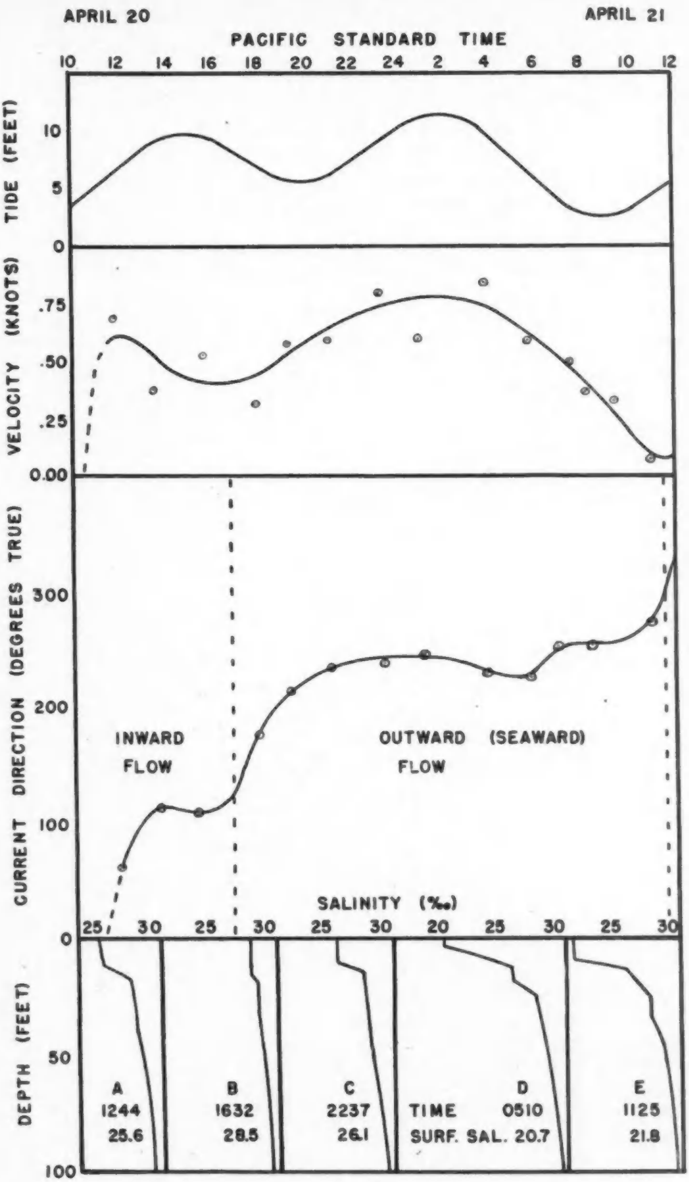

Figure 2. Station 25. The graphs show the relation of (*a*) current direction and speed to height of tide and (*b*) salinity structure to current direction. Note that the cycle of currents is apparently daily while tidal rise and fall are semi-daily.

at anchor, and it was necessary to work from a skiff secured to the shortest possible anchor line.

The temperature structure was observed with a shallow bathythermograph every three hours at the anchor stations. Serial salinity observations were made at the same time at small intervals of depth with Nansen-Knudsen reversing water sampling bottles.

Synoptic surveys of the oceanographic structure in the Loudoun Channel area were made on April 4 and April 25 (Figure 1). In addition, observations were made at five positions (stations 10-14), across the mouth of the channel, on April 8, and at seven positions (stations 16 to 22) in Alberni Inlet, Trevor Channel, and Imperial Eagle Channel on April 17.

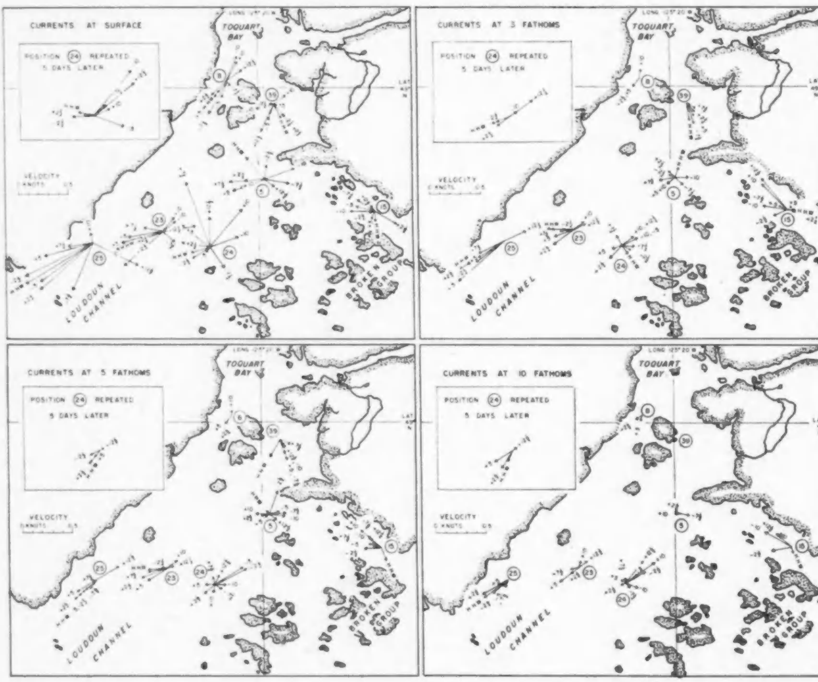

FIGURE 3. Observed currents in the vicinity of Loudoun Channel, at depths of 0, 3, 5, and 10 fathoms. The numbers (−5, +2½, etc.) represent hours before (−) or after (+) higher water. Times of zero current are omitted.

April 12-13	Station 15
17-18	5
19	24
20-21	25
21-22	8
22-23	23
24	24
25-26	39

OBSERVATIONS AND CONCLUSIONS

Current Measurements

The speed and direction of the current observed at each of the four depths, 0, 3, 5, and 10 fathoms, at each station, were plotted with time. The estimated best smooth curves were then drawn through the points (Figure 2) and current vectors were taken from these curves at intervals of 2½ hours, reckoned from the time of higher high water (Figure 3). The sum of 10 consecutive vectors is proportional to the net flow at the point of observation in a tidal day (Figure 4).

Current velocities in general were greatest at the surface and decreased with increasing depth. The typical variation with depth at station 23 is shown graphically in Figure 5.

Figures 2 and 3 show that the tidal current cycle was rotary but with the major flow in two opposing directions. They also show that, while the tidal rise was semi-daily, the apparent cycle of currents was daily.

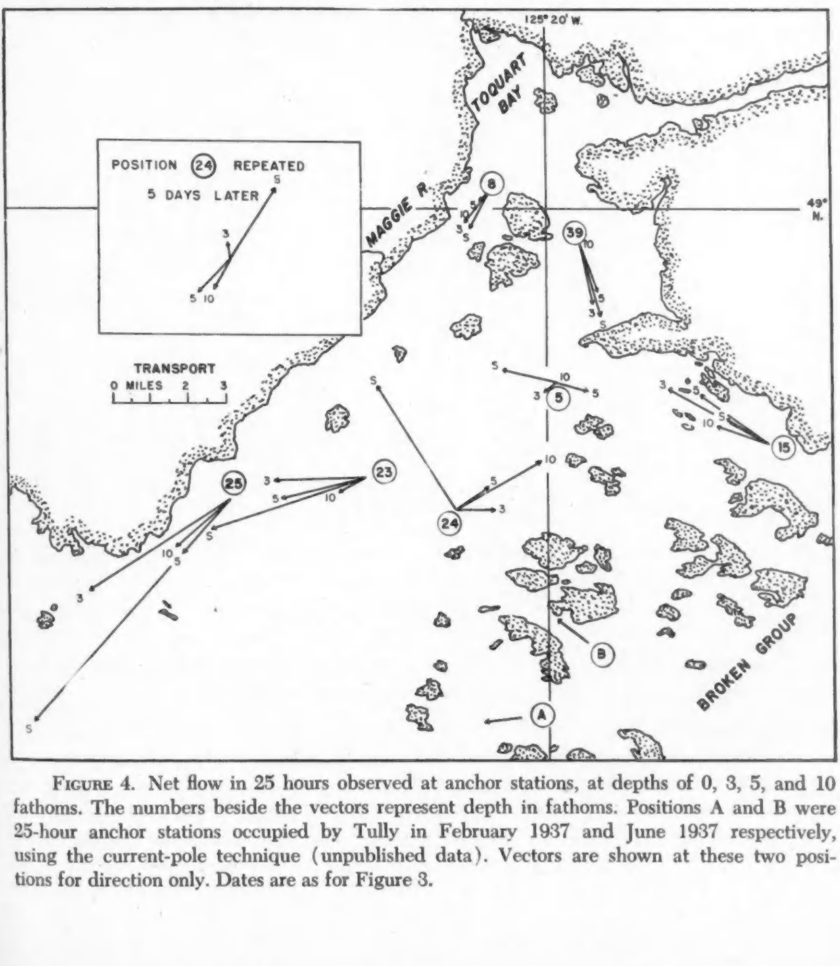

Figure 4. Net flow in 25 hours observed at anchor stations, at depths of 0, 3, 5, and 10 fathoms. The numbers beside the vectors represent depth in fathoms. Positions A and B were 25-hour anchor stations occupied by Tully in February 1937 and June 1937 respectively, using the current-pole technique (unpublished data). Vectors are shown at these two positions for direction only. Dates are as for Figure 3.

At stations 23, 24, and 25, across the main part of the channel, the surface current was seaward for some 12 hours, from six or seven hours before to six hours after higher high water, and was very much stronger on the northwest side (Station 25) than on the southeast side (Station 24). At the same time the deeper currents were seaward at Station 25, seaward or negligible at 23, and up-channel at 24. That is, on the northwest side the flow was seaward at all depths to 10 fathoms, while on the southeast it was seaward at the surface but

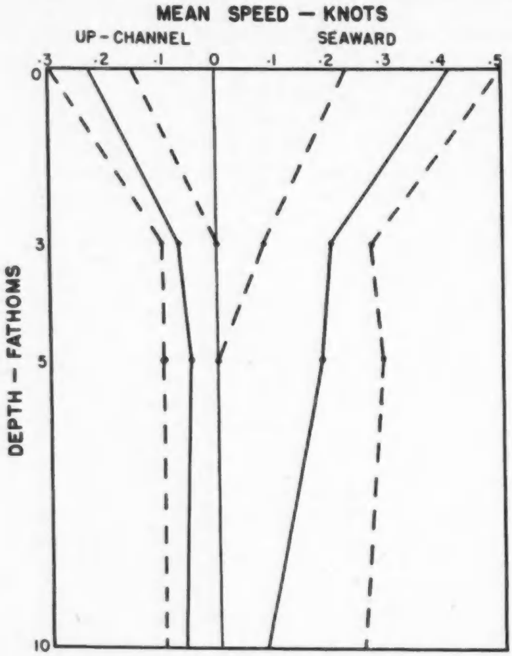

Figure 5. Mean speeds of seaward and up-channel currents observed at station 23. The broken lines indicate the limits of observed variations.

inward or up-channel at 3 fathoms and greater depths. The water required for the rising tide before higher high water must have been supplied by this deep counter-flow on the southeast side, and possibly also by the currents entering Loudoun Channel through the Broken Group.

During the remainder of the day the currents were relatively strong and directed up-channel at Station 24. At Station 23 they were up-channel but much reduced in speed. At Station 25 they were up-channel only for a short time and were cross-channel or negligible during the rest of the period.

The resulting net daily flow, or daily transport, represented in Figure 4, indicates that the main discharge from the system occurred along the northwest side to the Pacific Ocean. At the same time there was a net inward or counter-flow along the southeast side. There was also a net inflow from Imperial Eagle

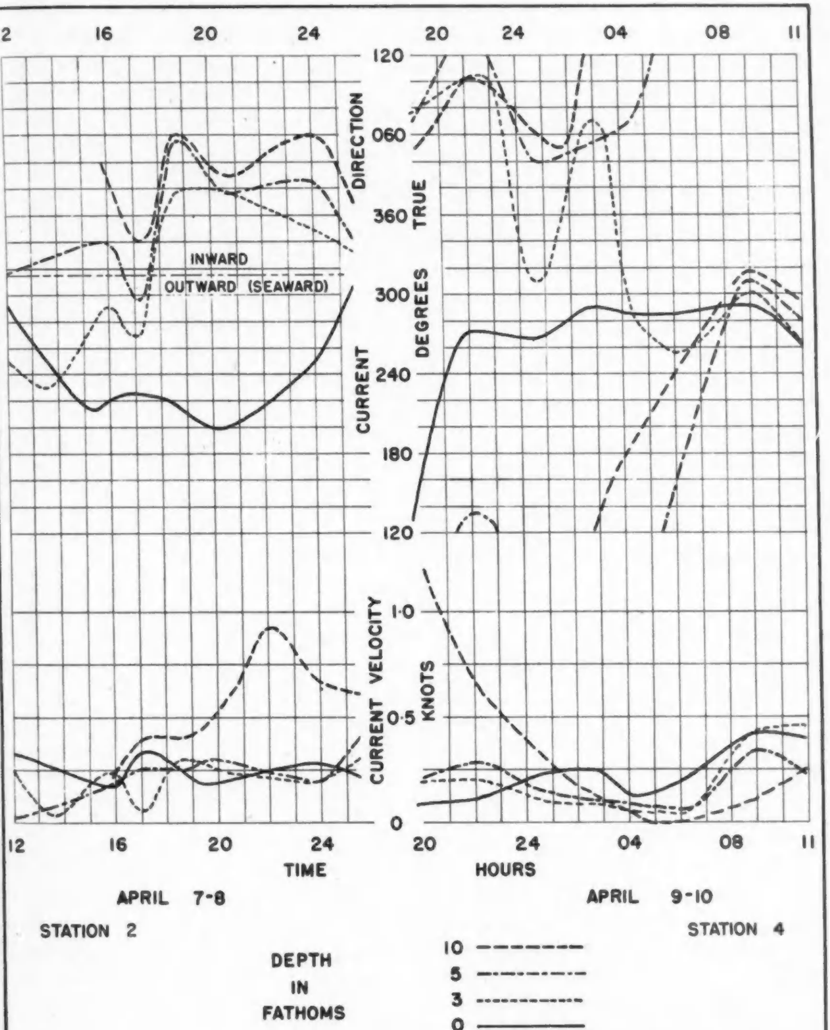

FIGURE 6. Graphs of current direction and speed observed at stations 2 and 4, showing the deep flow moving counter to the surface current.

Channel via the Channels through the Broken Group (Station 15). It will be shown that this latter inflow brings with it some of the fresh water from the Somass River at the head of Alberni Inlet.

Of the stations illustrated in Figures 3 and 4, numbers 23, 24 (twice), and 25 were occupied between April 19 and 24. Examination of Figure 3 shows that the current cycles observed at these three stations appear to be mutually consistent. It is unlikely, therefore, that the pattern of flow changed significantly during this period.

Earlier in the month several anchor stations were attempted (Table I) but were abandoned before completion because of rough weather or other difficulties. Station 2 on April 7 was occupied for some 15 hours. During 10 hours (Figure 6) a deep up-channel current was observed while the surface current was flowing to seaward. The trend in the data appears to indicate that the surface flow was changing to the up-channel direction when the observations were discontinued. If this was the case, there almost certainly was an up-channel bias in the net daily flow at the greater depths, which contrasts with the observations at Station 25, in practically the same position (Figure 1), on April 20-21. That is, on April 7 deep counter currents were observed while the surface flow was seaward, and there was probably an up-channel bias or transport at the deeper levels, while on April 20-21 no counter-flow was observed and the net movement was seaward at all levels. These contrasts indicate that there was a difference either in degree or in kind between the flow patterns on April 8 and April 25.

The current cycle at Station 5, April 17-18, appears reasonably consistent with those observed at Stations 23, 24, and 25. It seems likely, therefore, that Station 5 was associated with the latter flow pattern. Station 15, April 12–13, on the other hand, is not so clearly related to this pattern, and there appears to be some contradiction between the vectors at 3 and 5 fathoms depth and 5, 7½, and 10 hours before higher high water at Stations 5 and 15. It is thus possible that Station 15 was associated with an earlier, rather than the later type of flow and hence, that a change occurred between April 13 and 17.

What has been called the later flow pattern was characterized on the northwest side by a net outflow at all depths and the absence of deep counter-currents, and on the southeast side by deep counter-currents but a net inflow at all depths. The boundary between seaward and up-channel transport was thus primarily vertical. In the earlier period the presence of a deep counter-flow at both Stations 2 and 4 indicates that the outflow proceeded in the "upper zone" while a counter-flow occurred beneath it, and suggests that the boundary between seaward and up-channel transport was essentially horizontal. This relation appears reasonably well established for the later period, but for the earlier period is inferred from an incomplete series of observations.

Salinity Observations

When a river enters the sea in the northern hemisphere, the low salinity water formed by the mixing of fresh and sea water may be expected to veer to the right, in the absence of other currents, and follow the right-hand shore as

it moves away from the river mouth. In Loudoun Channel both the Maggie and Toquart Rivers enter on the northwest side. Low salinity surface water was found all along this side to the mouth of the channel (Figures 7 and 8). This fact, combined with the observed bias of currents, and the variation of salinity structure at Station 25, described below, supports the conclusion that the main discharge of fresh water from the system occurs along the northwest side of the channel.

Figure 9 shows surface salinities on April 17 from the mouth of Alberni Inlet to Sechart Channel. It appears from this figure that some of the fresh water from Alberni Inlet finds its way through Junction Passage to Imperial Eagle

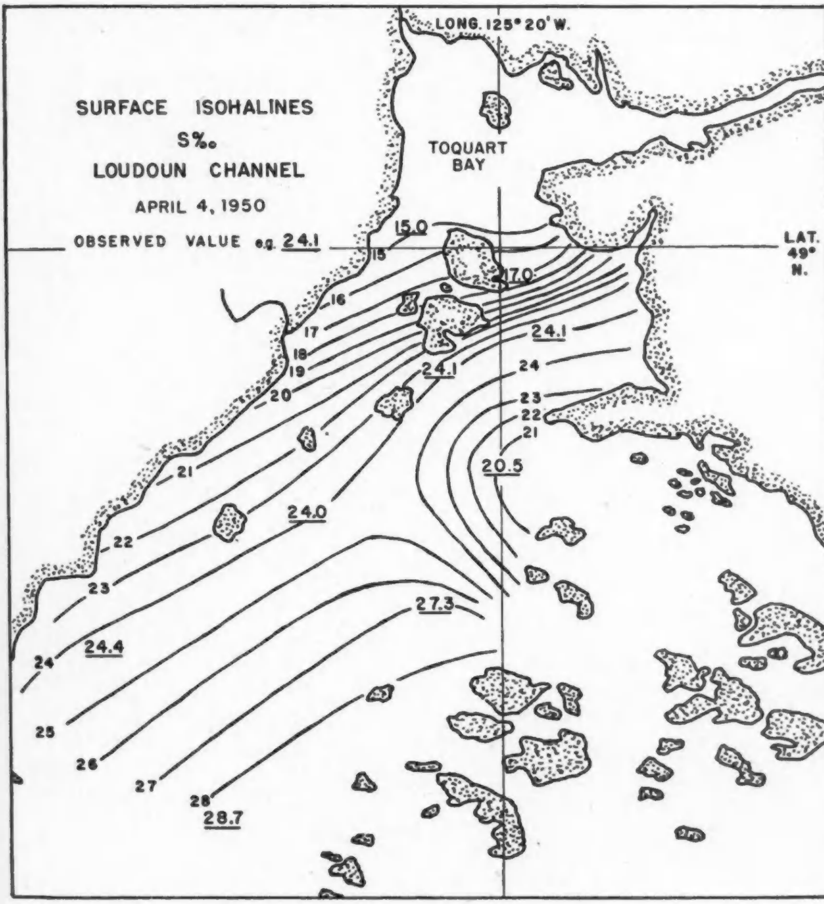

FIGURE 7. Surface isohalines in Loudoun Channel, April 4, 1950. Positions of observed values (underlined) are marked by the decimal point.

Channel. Here it tends to follow the right-hand shore until it reaches Sechart Channel through which it passes to Loudoun Channel. This agrees with the observed bias of currents by float measurements at Station 15 (Figure 4).

Attempts to trace continuity of types of vertical salinity profile in the synoptic surveys were not generally successful. The profiles obtained in the survey of April 25, have been reproduced in Figure 10.

As shown in Figure 2, a marked variation of salinity structure accompanied the change in direction of the tidal current at station 25. The graph of direction shows that the current was flooding from about 1200 to 1600 hours. During this time the profile changed from A at 1244 to B at 1632 hours, indicating an increase of salinity, especially in the upper zone.

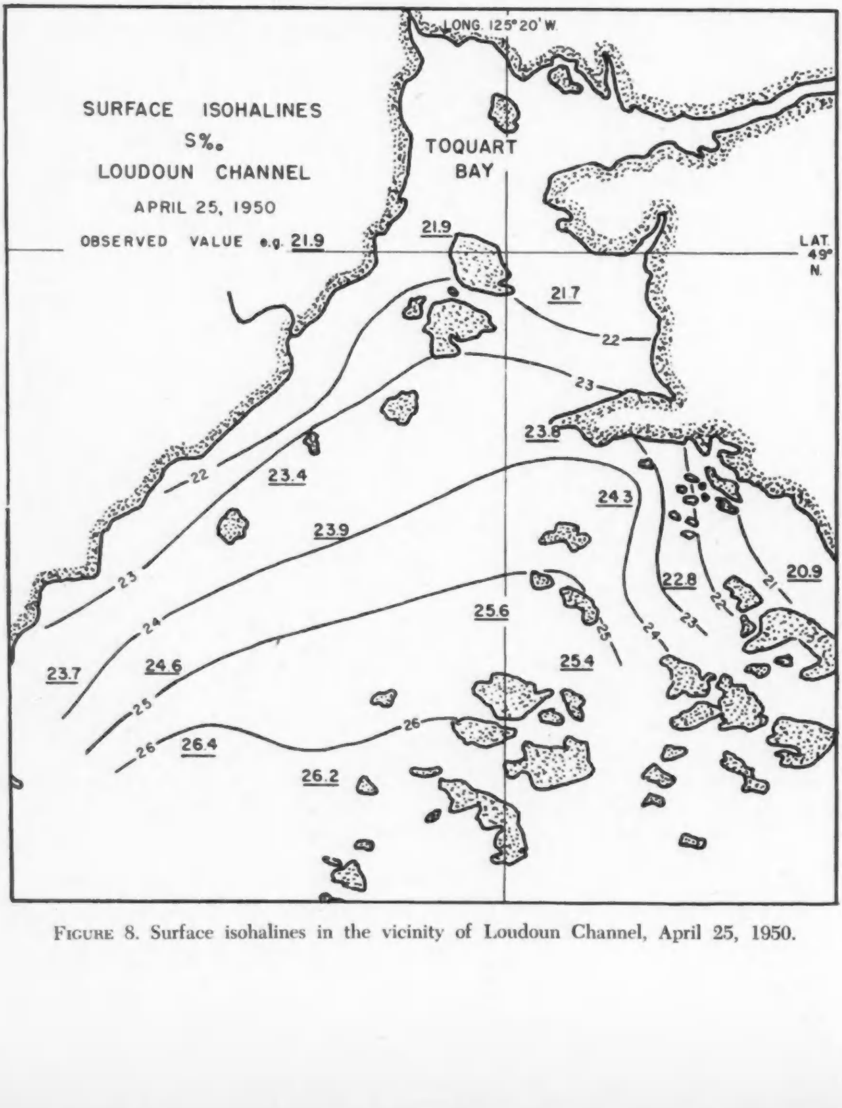

Figure 8. Surface isohalines in the vicinity of Loudoun Channel, April 25, 1950.

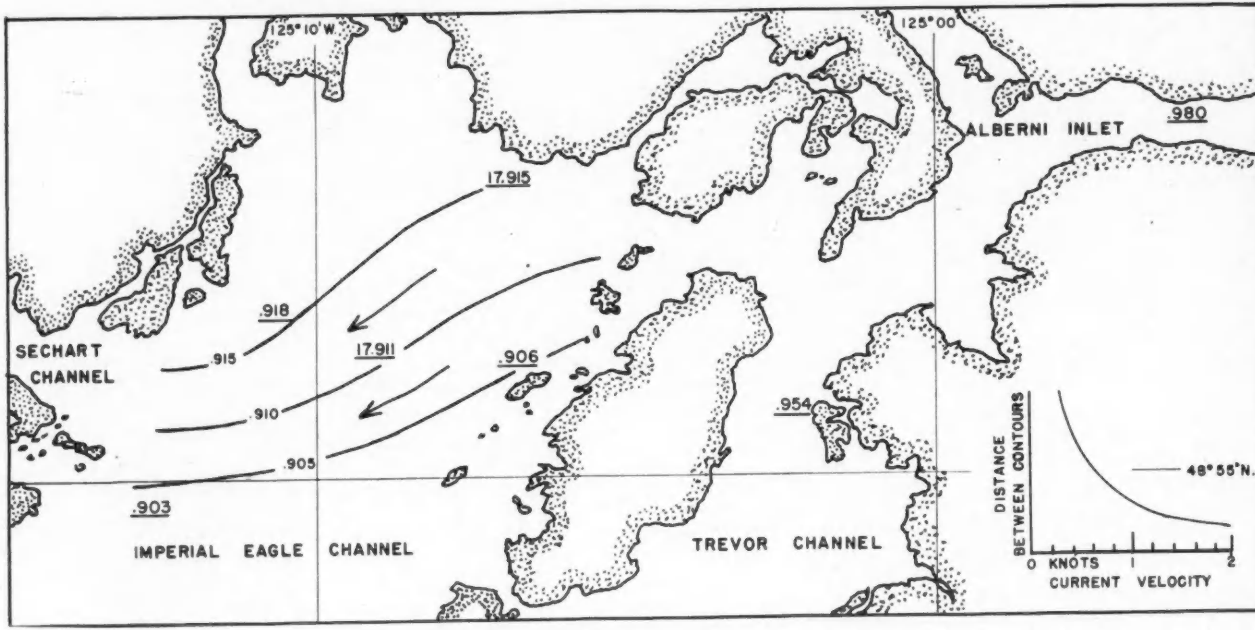

FIGURE 15. Calculated geopotential topography of the sea surface and gradient currents referred to the 18.3 decibar surface in Imperial Eagle Channel, April 17, 1950. Numbers represent dynamic meters. Observed values are underlined.

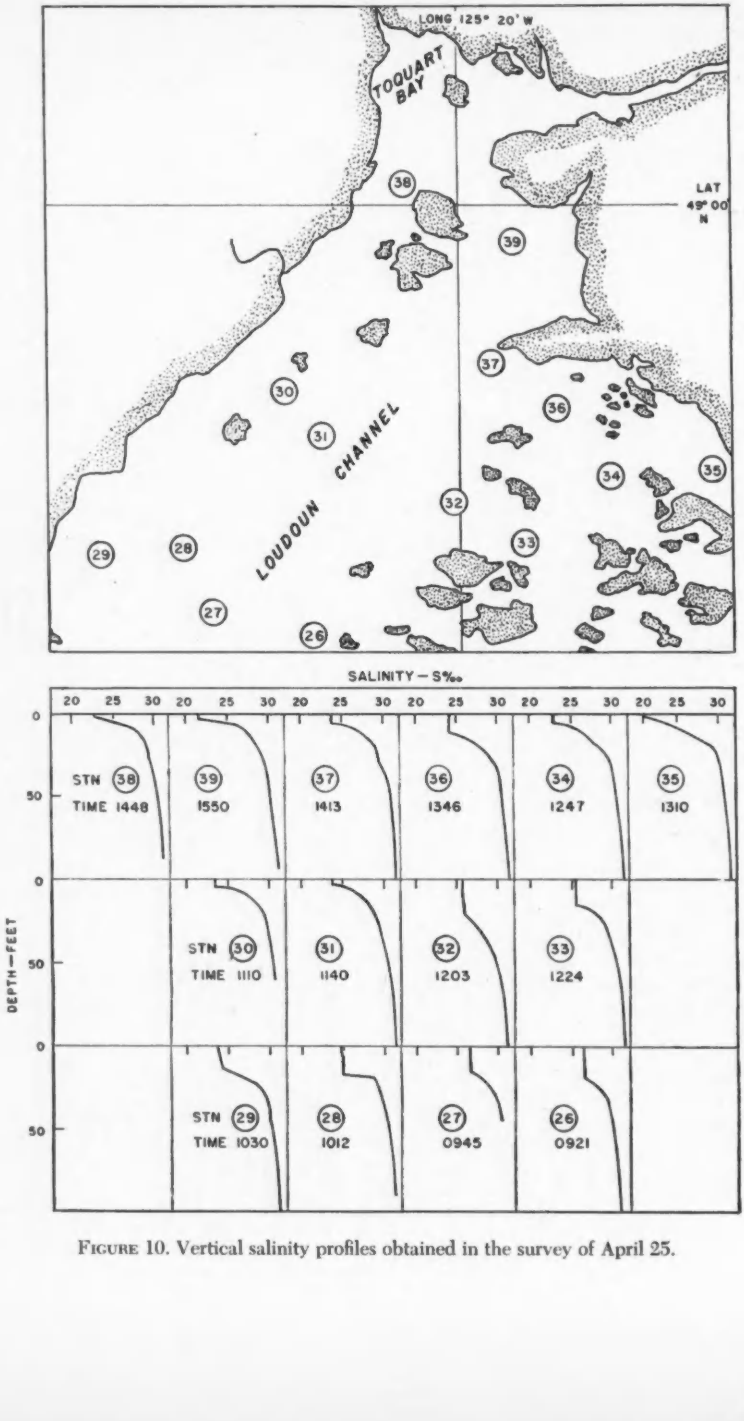

FIGURE 10. Vertical salinity profiles obtained in the survey of April 25.

From about 1800 the flow was seaward, and continued in this direction until noon the next day. The structure accompanying this seaward flow represents the fresh water of the system being discharged to the ocean. As the flood current develops (profiles A and B) salt water moves in from seaward and effectively blocks the discharge of fresh water, which is then temporarily confined within the system, since apparently there is little discharge along other routes. When the current ebbs, this accumulated river water is carried towards the ocean

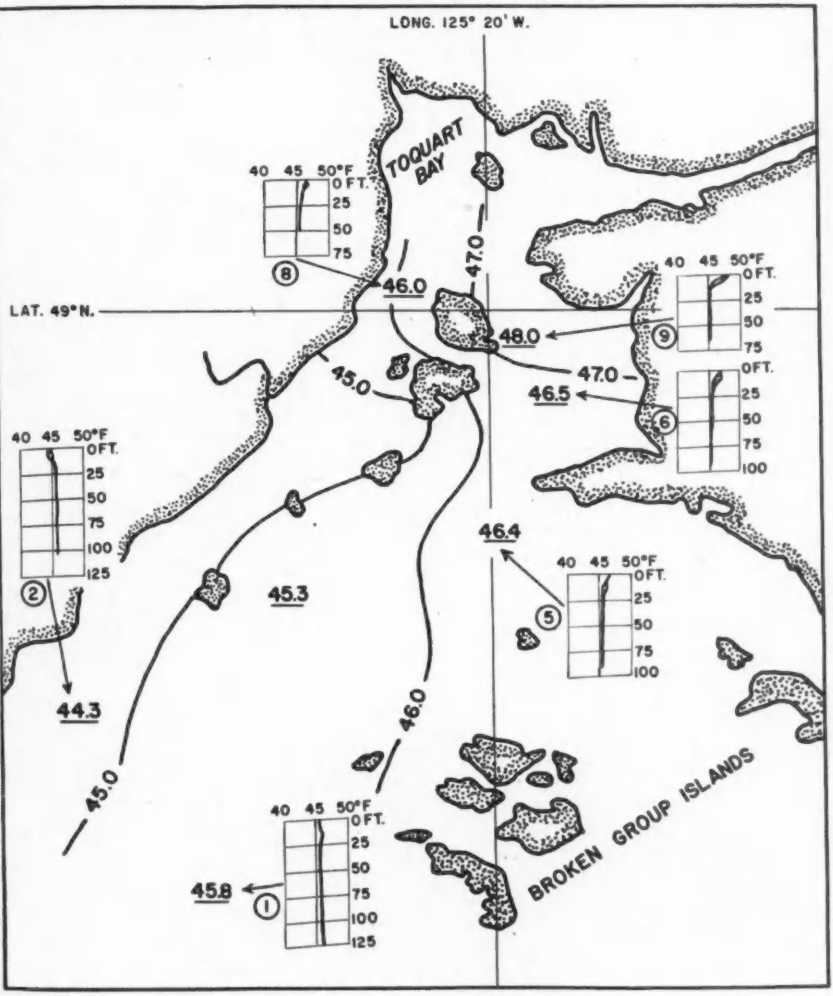

FIGURE 11. Surface temperatures observed in the survey of April 4. Inserts are traces of temperature vs. depth obtained with a shallow bathythermograph.

(profiles C, D, E). The decrease in salinity at Station 25 during this ebb period represents the outwards passage of such a mass of fresh water. When the current again turns to flood, that proportion of the mass which has reached the ocean will probably be detached from the stream and float away as a "cloud" until it loses its identity by dissipation. Part of the mass, which has not moved completely out of the channel, will be caught by the next flood and swept back into the mouth of the channel, contributing to the general distribution of upper zone water throughout the area.

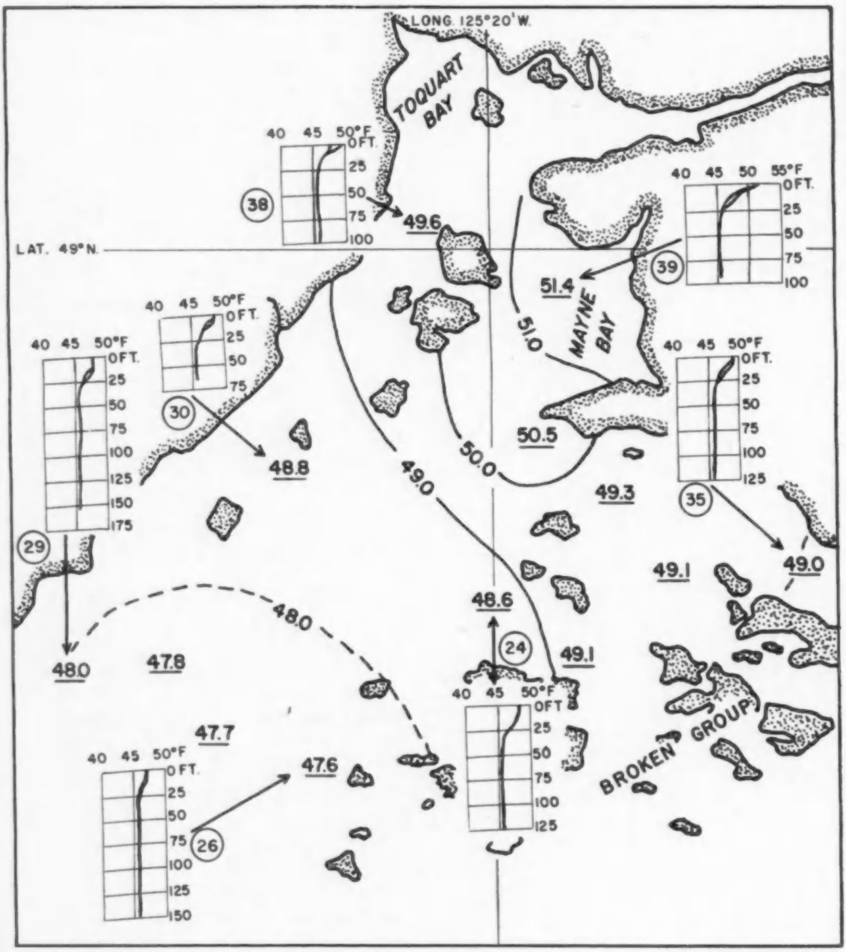

Figure 12. Surface temperatures observed in the survey of April 25. Inserts are traces of temperature vs. depth obtained with a shallow bathythermograph.

Similar changes of structure occurred but were not as pronounced at the other stations.

TEMPERATURE OBSERVATIONS

In both synoptic surveys, the thermocline, where it occurred, was less than 30 feet below the surface. Below this, the water was practically isothermal over the whole region (mean 45.4°F. on April 4, and 45.9° on April 25).

On April 4 (Figure 11) a relatively warm surface layer (47°–48°) was found in the Toquart Bay region. From here, there was a gradual decrease in temperature towards Station 2 at the mouth of the channel where the surface

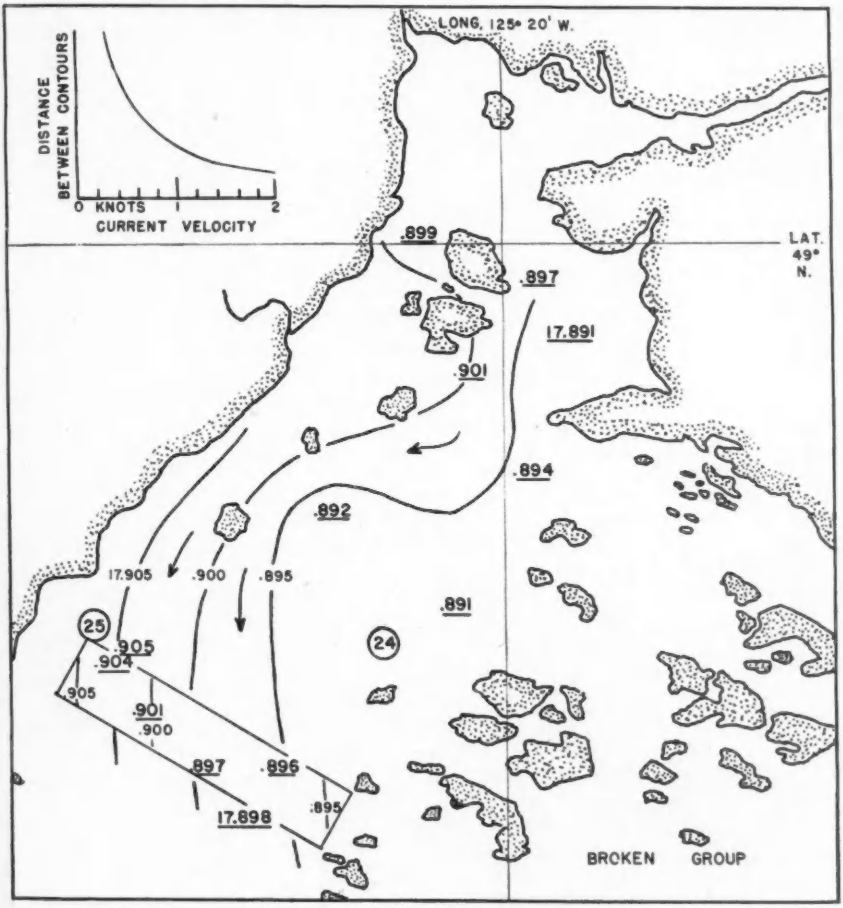

FIGURE 13. Calculated geopotential topography of sea surface and gradient currents referred to the 18.3 decibar surface in Loudoun Channel, April 4, and April 8 (insert), 1950. Numbers represent dynamic meters. Observed values are underlined.

layer (44°F.) was about two degrees colder than the underlying isothermal water. At Station 1, on the Broken Group side of the channel, the water was nearly isothermal from the surface downwards (46°F.).

By April 25 (Figure 12) the surface water had become warmer over the whole region, but the relative distribution of temperatures was similar. The warmest part was the Toquart and Mayne Bay area (50°–51°F.), while temperatures gradually fell to 48°F. at stations near the mouth.

Gradient Currents

Figures 3, 4, and 5 show that the currents and transports observed at a depth of 10 fathoms were small compared to those at the surface. Therefore it is

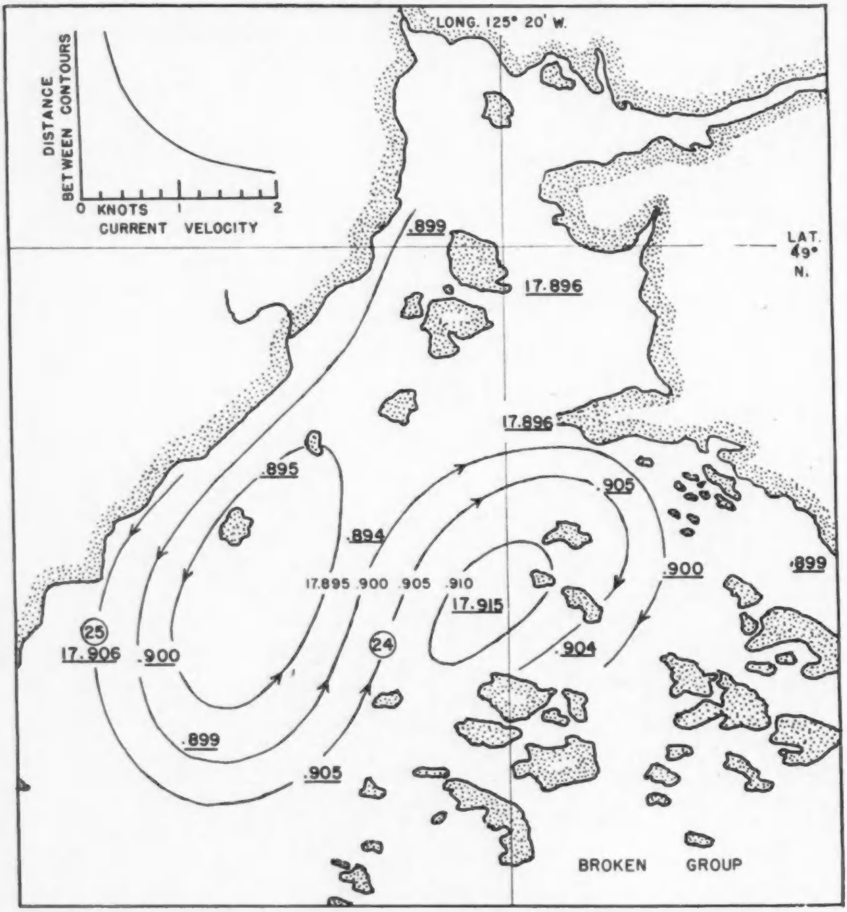

FIGURE 14. Calculated geopotential topography of sea surface and gradient currents referred to the 18.3 decibar surface in Loudoun Channel, April 25, 1950. Numbers represent dynamic metres. Observed values are underlined.

interesting to note that gradient currents (Figures 13, 14, and 15) calculated relative to the 18.3 decibar surface (18.3 metres = 10 fathoms) agree qualitatively with the patterns of flow inferred from the other data. Even if this agreement is discounted as fortuitous, since the validity of such calculations has not been demonstrated for this system, the contrast between the earlier and later forms is none the less striking. In Figure 13 the gradient of the sea surface implied by the four observations on April 8 (insert) is similar to that observed on April 4. Since anchor Station 2 (April 7) fell between these two dates, and was the chief indication of a difference between earlier and later flow patterns, it seems probable that the calculated gradients of Figure 13 were associated with the earlier type flow. The striking difference between Figures 13 and 14, on the other hand, supports the conclusion that the flow pattern on the 25th and hence, probably, throughout the second half of the month, was not the same as in the earlier period.

Discussion

It has been deduced that two different patterns of flow existed in the earlier and later parts of the month. Factors contributing to the change may include the daily tidal range, winds, and the rate of land drainage.

TABLE II. Wind velocities (m.p.h.) recorded twice daily at Pachena Point and Estevan Point Light Stations. Northwest components have been assigned plus (+) and southeast components minus (−) values.

	Winds at Pachena		Winds at Estevan	
Date	A.M.	P.M.	A.M.	P.M.
April 1	NW 15 (+15)	W 15 (+11)	W 18 (+13)	S 28 (−20)
2	NW 10 (+10)	NW 30 (+30)	N 8 (+ 6)	W 15 (+11)
3	SW 10 (0)	NW 15 (+15)	NW 8 (+ 8)	NW 25 (+25)
4	SE 25 (−25)	SE 28 (−28)	SE 12 (−12)	W 6 (+ 4)
5	SE 30 (−30)	SE 40 (−40)	SE 25 (−25)	SE 9 (− 9)
6	SE 15 (−15)	S 25 (−18)	SE 12 (−12)	SE 25 (−25)
7	E 15 (−11)	SE 23 (−23)	NE 5 (0)	SE 16 (−16)
8	S 3 (− 2)	NW 18 (+18)	NW 10 (+10)	NW 4 (+ 4)
9	NW 5 (+ 5)	S 3 (− 2)	W 8 (+ 6)	NW 30 (+30)
10	SE 25 (−25)	SE 35 (−35)	SE 30 (−30)	SE 10 (−10)
11	SE 45 (−45)	S 35 (−25)	SE 36 (−36)	SE 25 (−25)
12	S 25 (−18)	S 10 (− 7)	S 28 (−20)	SE 25 (−25)
13	S 15 (−11)	SW 3 (0)	SW 8 (0)	S 18 (−13)
14	SE 40 (−40)	SE 40 (−40)	SE 35 (−35)	SW 6 (0)
15	S 20 (−14)	NW 10 (+10)	NW 14 (+14)	SE 32 (−32)
16	S 40 (−28)	NW 25 (+25)	S 35 (−25)	NW 9 (+ 9)
17	NW 4 (+ 4)	NW 15 (+15)	N 1 (+0.7)	NW 28 (+28)
18	SE 10 (−10)	SE 25 (−25)	S 6 (− 4)	NW 18 (+18)
19	SE 25 (−25)	SE 20 (−20)	SE 6 (− 6)	W 9 (+ 6)
20	NW 25 (+25)	NW 25 (+25)	NW 30 (+30)	SE 9 (− 9)
21	SE 7 (− 7)	SW 4 (0)	SE 8 (− 8)	NW 18 (+18)
22	NW 15 (+15)	NW 20 (+20)	0 (0)	SE 5 (− 5)
23	SE 10 (−10)	SE 4 (− 4)	N 6 (+ 4)	N 12 (+ 8)
24	SE 18 (−18)	SE 15 (−15)	SE 16 (−16)	S 8 (− 6)
25	NW 25 (+25)	NW 25 (+25)	NW 15 (+15)	SE 20 (−20)
26	SE 25 (−25)	SE 32 (−32)	SE 18 (−18)	NW 25 (+25)

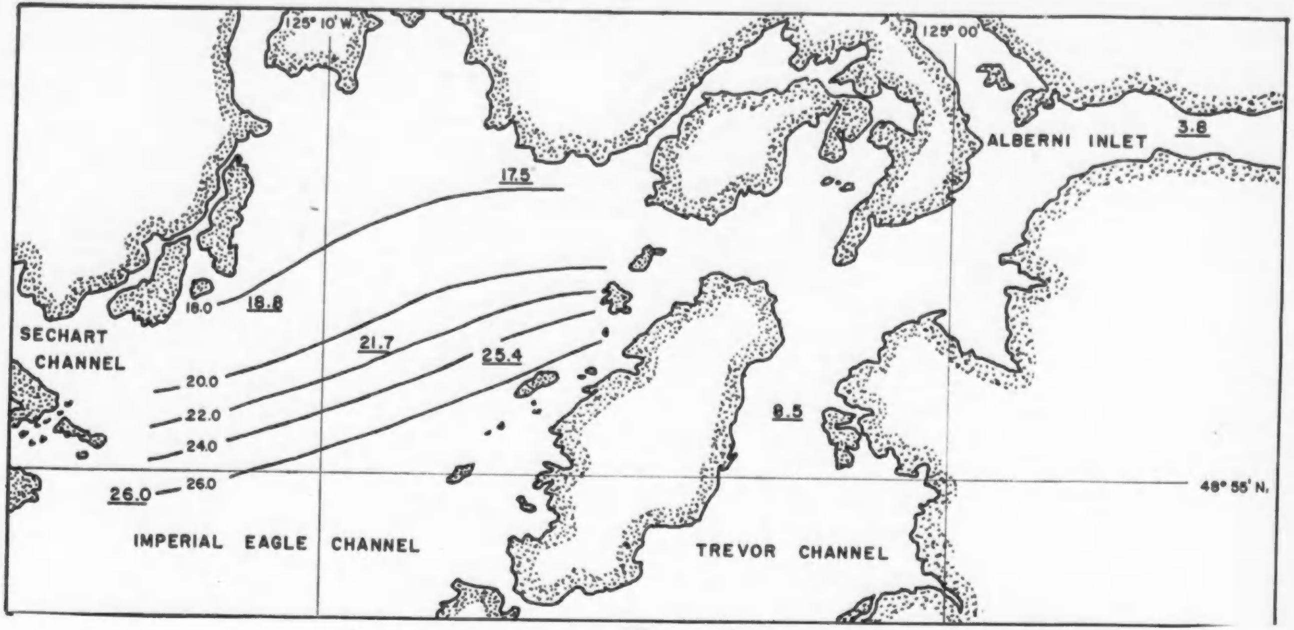

FIGURE 9. Surface isohalines in Imperial Eagle Channel, April 17, 1950.

No immediate relation is apparent between the differences of tidal configuration and the postulated differences of flow, since both periods included the full range from spring to neap tides.

Wind does not appear to have caused the change. Wind velocities recorded twice daily at Pachena Point, 16 miles southeast, and Estevan Point, 50 miles northwest of Loudoun Channel, throughout both periods are shown in Table II. Examination of the table shows that the predominant wind directions were northwest and southeast. Positive values have been assigned to the northwest components and negative values to the southeast components of all velocities and these have been plotted with time in Figure 16(A). It was inferred in the discussion

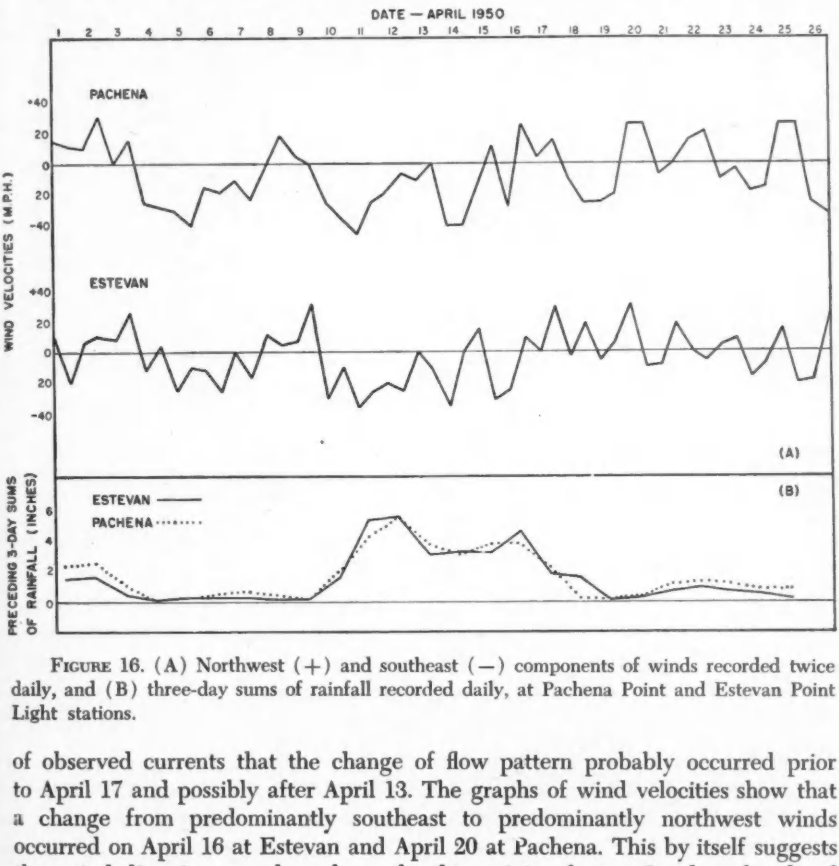

FIGURE 16. (A) Northwest (+) and southeast (—) components of winds recorded twice daily, and (B) three-day sums of rainfall recorded daily, at Pachena Point and Estevan Point Light stations.

of observed currents that the change of flow pattern probably occurred prior to April 17 and possibly after April 13. The graphs of wind velocities show that a change from predominantly southeast to predominantly northwest winds occurred on April 16 at Estevan and April 20 at Pachena. This by itself suggests that wind direction may have been the determining factor. On the other hand the northwest winds on April 8-9, and the southeast winds on April 18-19 and 23-24 were opposite to the main directions in their respective periods, and reduced the apparent correlation accordingly.

The fresh water in Loudoun Channel has been shown to come both from local drainage in the discharge of the Maggie and Toquart Rivers, and from the Somass River via Alberni Inlet, Imperial Eagle Channel, and the passages through the Broken Group Islands. The influence of these two will be considered separately.

Since figures are not available on the discharge of the Maggie and Toquart Rivers, records of rainfall at Pachena Point and Estevan Point have been used.

TABLE III. Daily rainfall, in inches, recorded at Pachena Point and Estevan Point Light Stations.

Date		Pachena Daily	Pachena 3-Day Sum	Estevan Daily	Estevan 3-Day Sum
March	29	.05	.57	.20	.53
	30	—	.21	—	.27
	31	1.11	1.16	1.40	1.60
April	1	.40	1.51	.92	2.32
	2	.10	1.61	.19	2.51
	3	—	.50	—	1.11
	4	—	.10	—	.19
	5	.28	.28	.25	.25
	6	.05	.33	.31	.56
	7	—	.33	.13	.69
	8	—	.05	—	.44
	9	.13	.13	.02	.15
	10	2.43	2.56	1.95	1.97
	11	2.69	5.25	2.20	4.17
	12	.31	5.43	1.36	5.41
	13	.04	3.04	.15	3.71
	14	2.82	3.17	1.62	3.03
	15	.25	3.11	2.01	3.78
	16	1.41	4.48	.11	3.74
	17	.05	1.71	.06	2.18
	18	—	1.46	—	.17
	19	.03	.08	.12	.18
	20	.30	.33	.29	.41
	21	.34	.67	.74	1.15
	22	.27	.91	.31	1.34
	23	—	.61	.12	1.17
	24	.17	.44	.36	.79
	25	—	.17	.31	.79

These two points bracket the area, and since the figures for the two are essentially proportional they have been taken as representative of the precipitation, and consequently of the runoff into Barkley Sound. Table III gives the daily rainfall, together with three-day sums during both periods at each of these places. Three-day sums have been used since individuals familiar with the area have expressed the opinion that two to four days is approximately the period required for the rivers to subside after heavy rain. These sums are represented graphically in Figure 16(B).

The week of April 9-16 was a period of heavy local discharge. But the levels of the graphs after the 16th do not appear to be significantly different from the levels before the 9th, and hence the difference between earlier and later types of flow is apparently not due to local runoff.

The rate of discharge of the Somass River is represented in Figure 17. The volume of flow on April 11 was approximately five times that on April 10. On the 22nd the rate was still three times as great, and on the 24th two and one-half times as great as on the 10th. If an allowance of a day or two is made for this

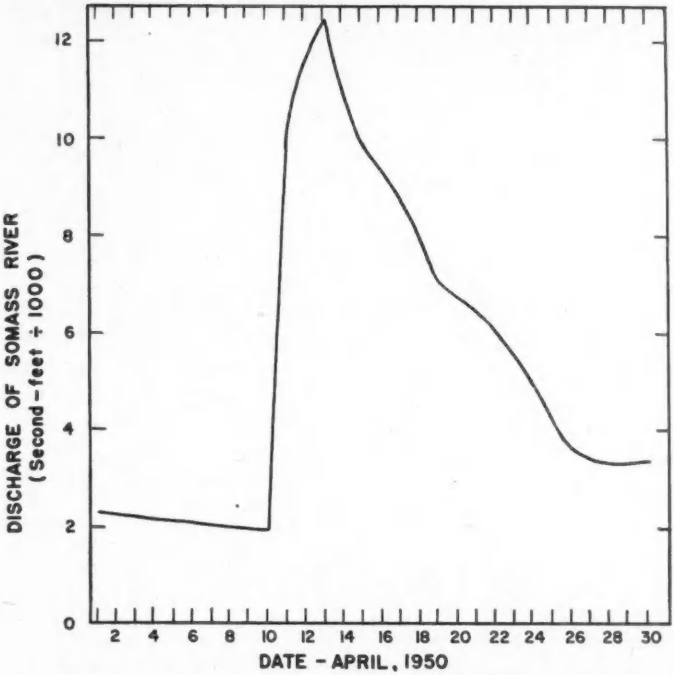

FIGURE 17. Discharge of the Somass River (at the head of Alberni Inlet) during the period of the investigation.

discharge to reach Loudoun Channel, the postulated change in flow pattern appears to have coincided with the freshet on the Somass. Since neither of the other factors examined has yielded a clear correlation with the change, the discharge of the Somass appears to be the most probable single cause.

SUMMARY

GENERAL OBSERVATIONS

1. Currents and net transports were greatest at the surface and were substantially smaller at three fathoms and greater depths (Figures 3, 4, and 5).
2. The current cycle was in general rotary. The apparent period of rotation was one day, while the tidal rise and fall was semi-daily (Figures 2 and 3).

3. There was a general distribution of low salinity upper zone water over the whole area (Figure 10), although surface salinities generally were lowest on the northwest side (Figures 7 and 8).
4. Surface waters were warmest at the head of the channel and coldest near the mouth (Figures 11 and 12).

Conclusions Regarding Pattern of Flow

1. The fresh water from the Maggie and Toquart Rivers is discharged principally along the northwest shore to the Pacific Ocean. Evidence: (*a*) the bias of currents (Figures 3 and 4); (*b*) surface salinities (Figures 7 and 8); (*c*) changes of vertical salinity structure (Figure 2).
2. Some of the low salinity water carrying the discharge from the Somass River (Alberni Inlet) finds its way via Imperial Eagle Channel and the Broken Group to Loudoun Channel. Evidence: (*a*) surface salinities (Figure 9); (*b*) the bias of currents at station 15 (Figure 4); (*c*) note also the calculated gradiant currents (Figure 15).
3. There appears to have been a significant change in the pattern of flow about the middle of the month. Evidence: (*a*) the presence of deep counter-current at Station 2 in the earlier part (Figure 6) and absence at Station 25 during the later part of the month (Figures 3 and 4); (*b*) the difference between the calculated gradient currents (Figures 13 and 14).
4. If such a change occurred it appears to have been associated with a sudden increase in the discharge of the Somass River. Evidence: Figure 17.
5. Local drainage does not appear to have been related to this change. Evidence: Figure 16(B).
6. Wind direction does not appear to have been consistently related to the change. Evidence: Figure 16(A).

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